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(12) United States Patent
Whited et al.

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(45) Date of Patent: Dec. 29, 2015

(54) **POWER OPERATED ROTARY KNIFE**

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(73) Assignee: **Bettcher Industries, Inc.**, Birmingham, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/279,582**

(22) Filed: **May 16, 2014**

(65) **Prior Publication Data**

US 2014/0245617 A1 Sep. 4, 2014

Related U.S. Application Data

(63) Continuation of application No. 13/189,938, filed on Jul. 25, 2011, now Pat. No. 8,726,524.

(51) **Int. Cl.**

B26B 7/00	(2006.01)
A22B 5/16	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC . ***B26B 7/00*** (2013.01); ***A22B 5/165*** (2013.01); ***A22C 17/12*** (2013.01); ***B26B 25/002*** (2013.01)

(58) **Field of Classification Search**

CPC B26B 25/002; B26B 29/00; A22C 17/12; A22B 5/165

USPC 30/276, 124, 142, 285

See application file for complete search history.

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(Continued)

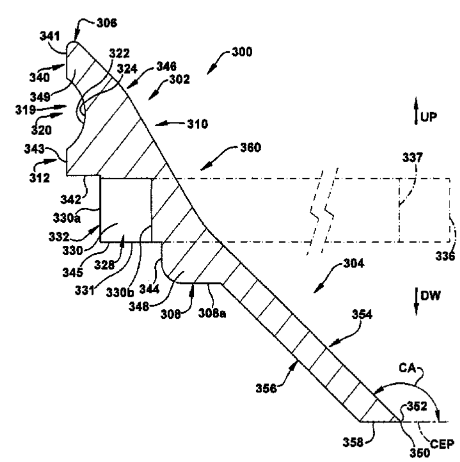
Primary Examiner — Sean Michalski

(74) *Attorney, Agent, or Firm* — Tarolli, Sundheim, Covell & Tummino, LLP

(57) **ABSTRACT**

A power operated rotary knife (**100**) including: an annular rotary knife blade (**300**) including a knife blade bearing surface (**319**); a blade housing (**400**) defining a blade housing bearing surface (**459**); and a blade-blade housing bearing structure (**500**) disposed between the knife blade bearing surface (**319**) and the blade housing bearing surface (**459**). The blade-blade housing bearing structure (**500**) includes a rolling bearing strip (**502**) having a plurality of rolling bearings (**506**), such as ball bearings, disposed in spaced apart relation in a flexible separator cage (**508**). The rolling bearing strip (**502**) traverses through an annular passageway (**504**) defined between the knife blade bearing surface (**319**) and the blade housing bearing surface (**459**) to secure the knife blade (**300**) to the blade housing (**400**) and support the knife blade for rotation about a central axis (R) with respect to the blade housing (**400**).

28 Claims, 133 Drawing Sheets



(51) **Int. Cl.**
A22C 17/12 (2006.01)
B26B 25/00 (2006.01)

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Oct. 3, 2011 Decision and Opinion of the United States Court of Appeals for the Federal Circuit (Appeal No. 2011-1038, -1046) regarding the case styled *Bettcher Industries, Inc.* v. *Bunzl USA, Inc. and Bunzl Processor Distribution, LLC*, Case No. 3:08 CV 2423, U.S. District Court for the Northern District Court for the Northern District of Ohio, Judge Zouhary. The Decision and Opinion relates to U.S. Pat. No. 7,000,325, owned by the assignee of the present application. (47 pages).

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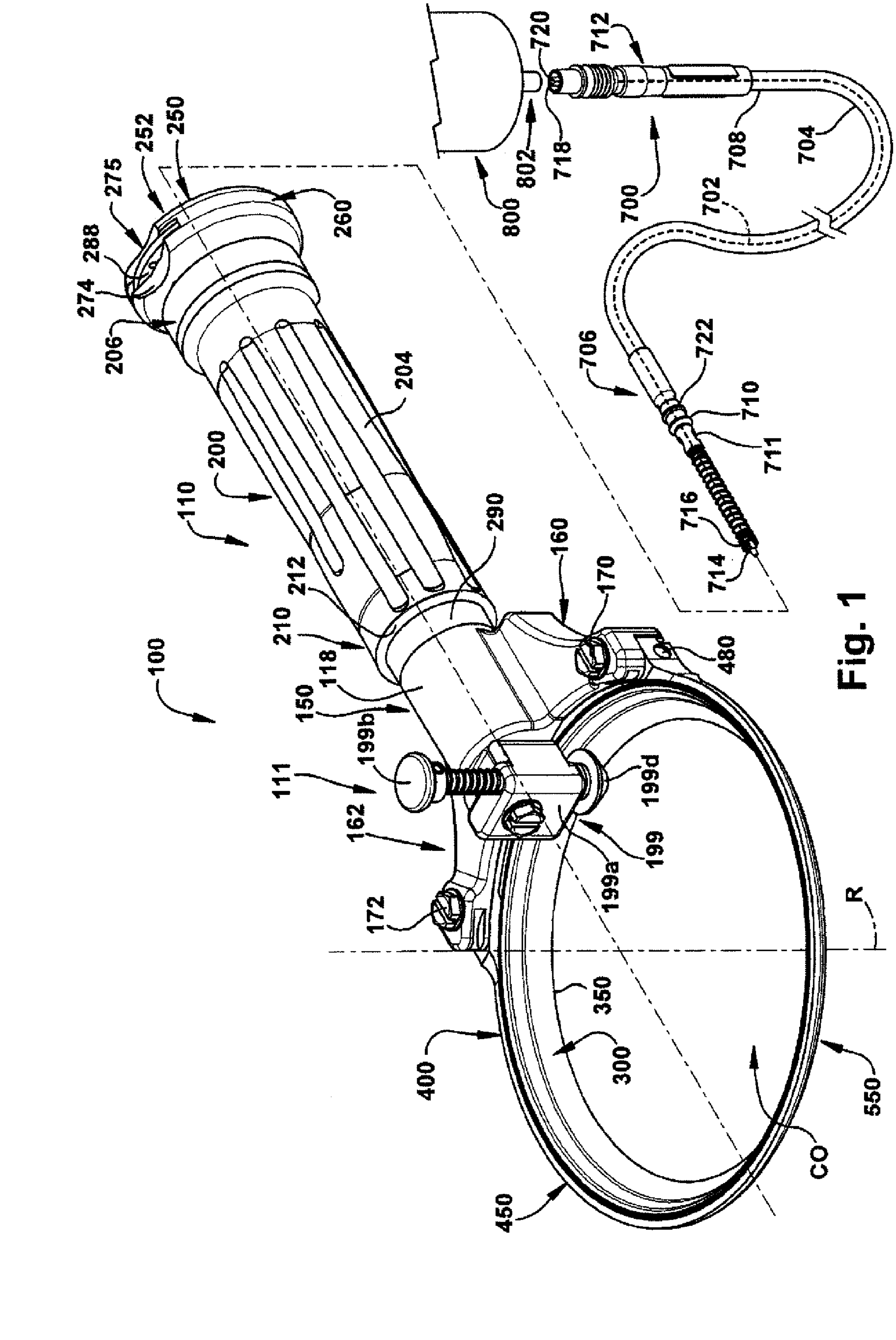
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Fig. 1

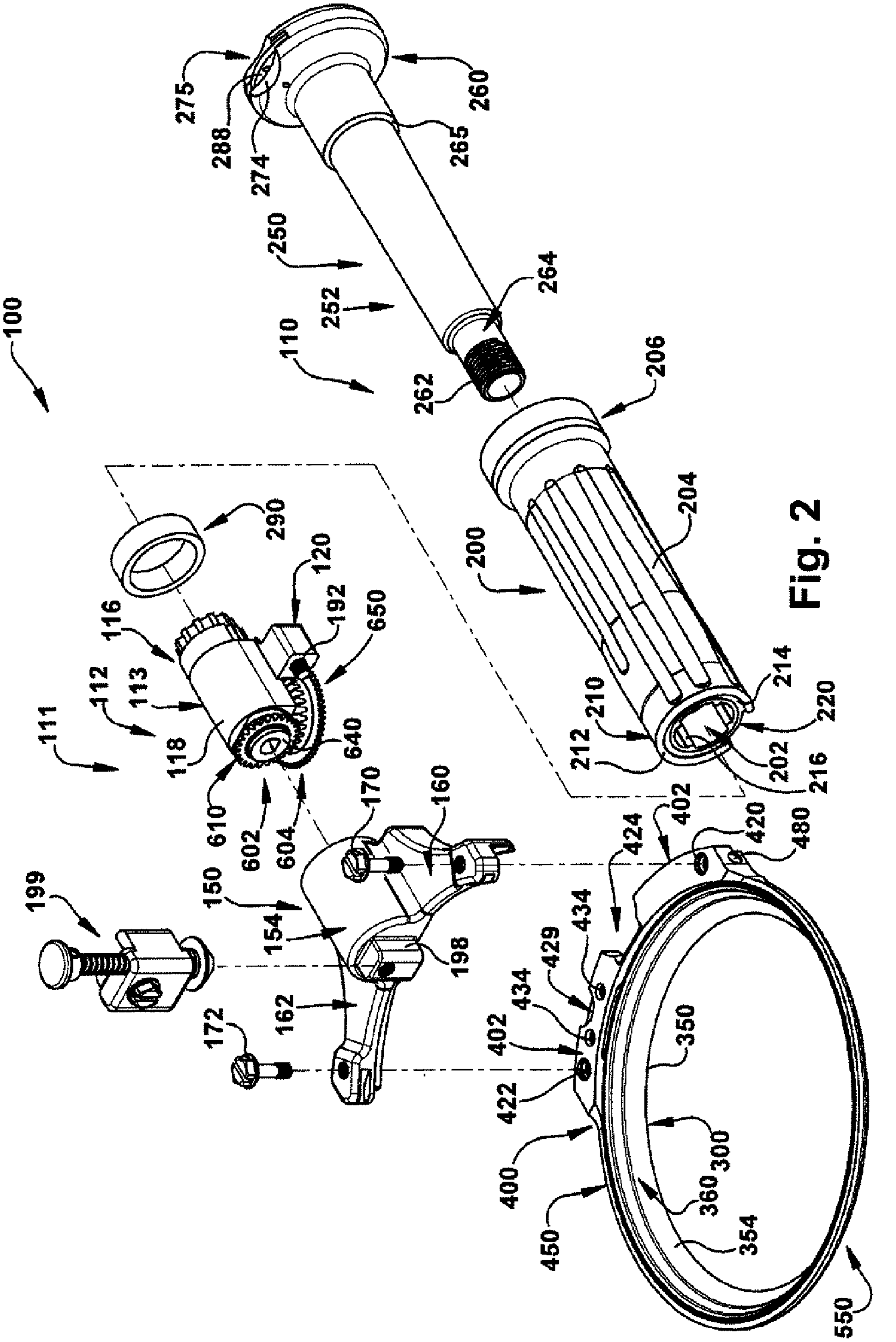
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Fig. 2

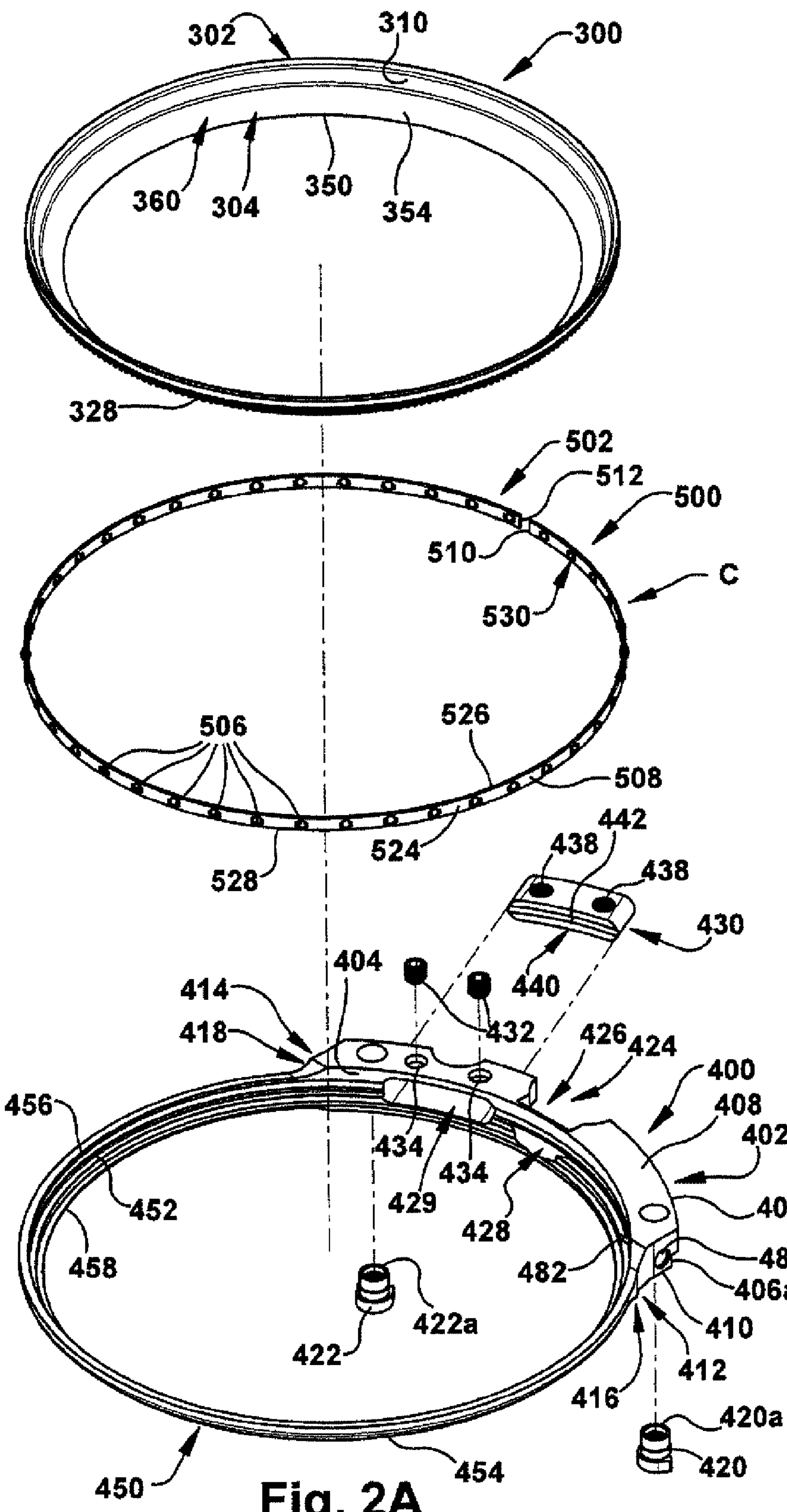
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Fig. 2A

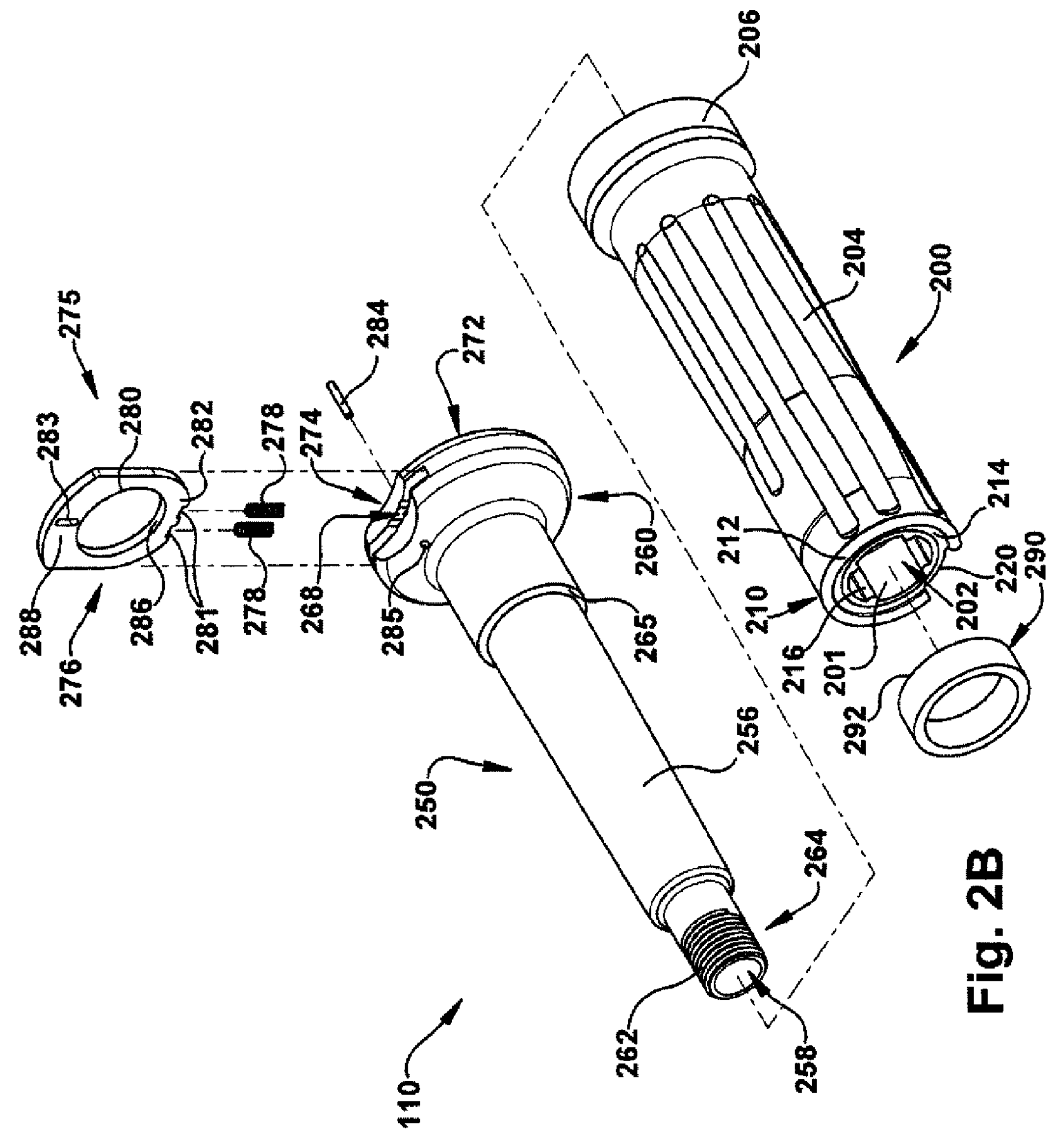
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Fig. 2B

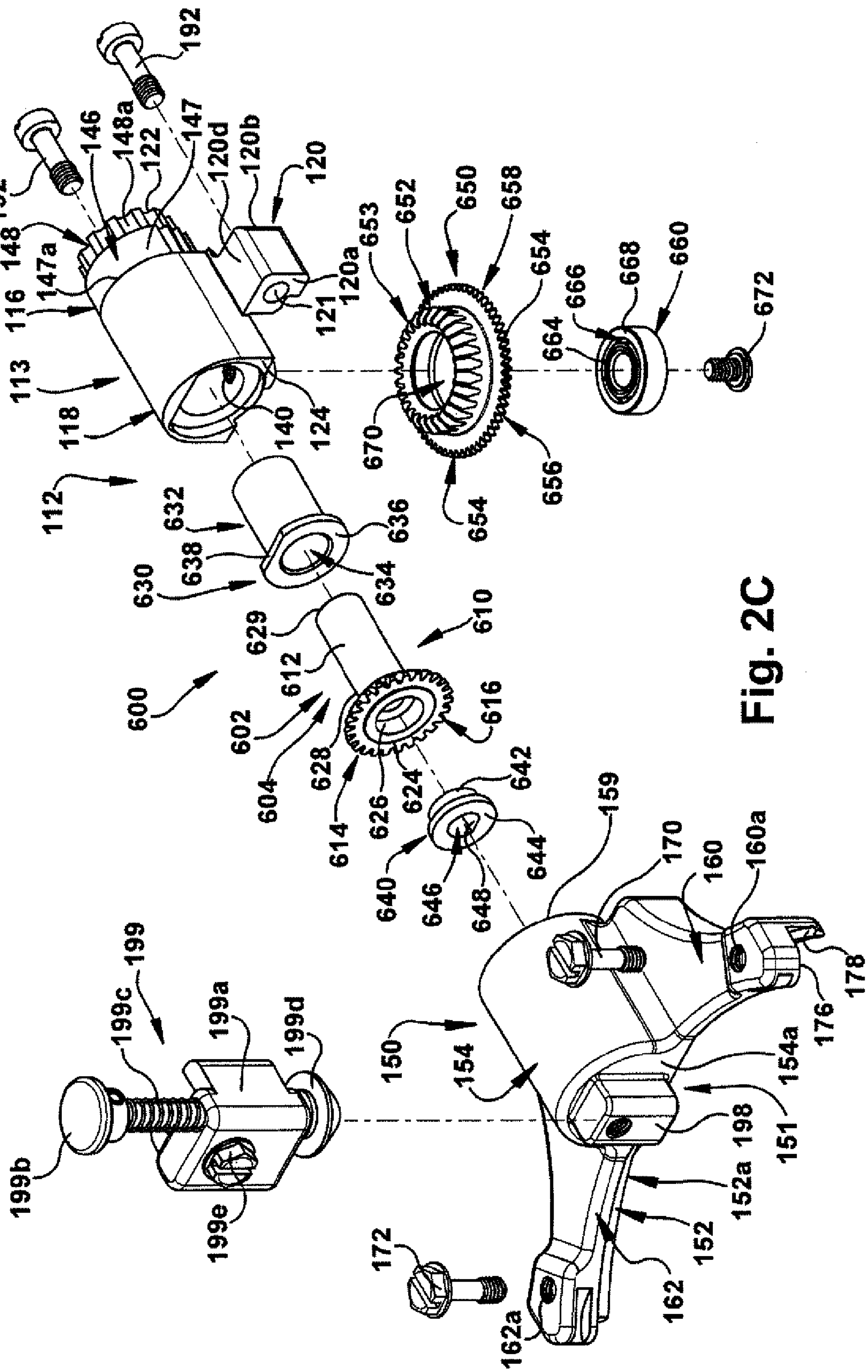
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Fig. 2C

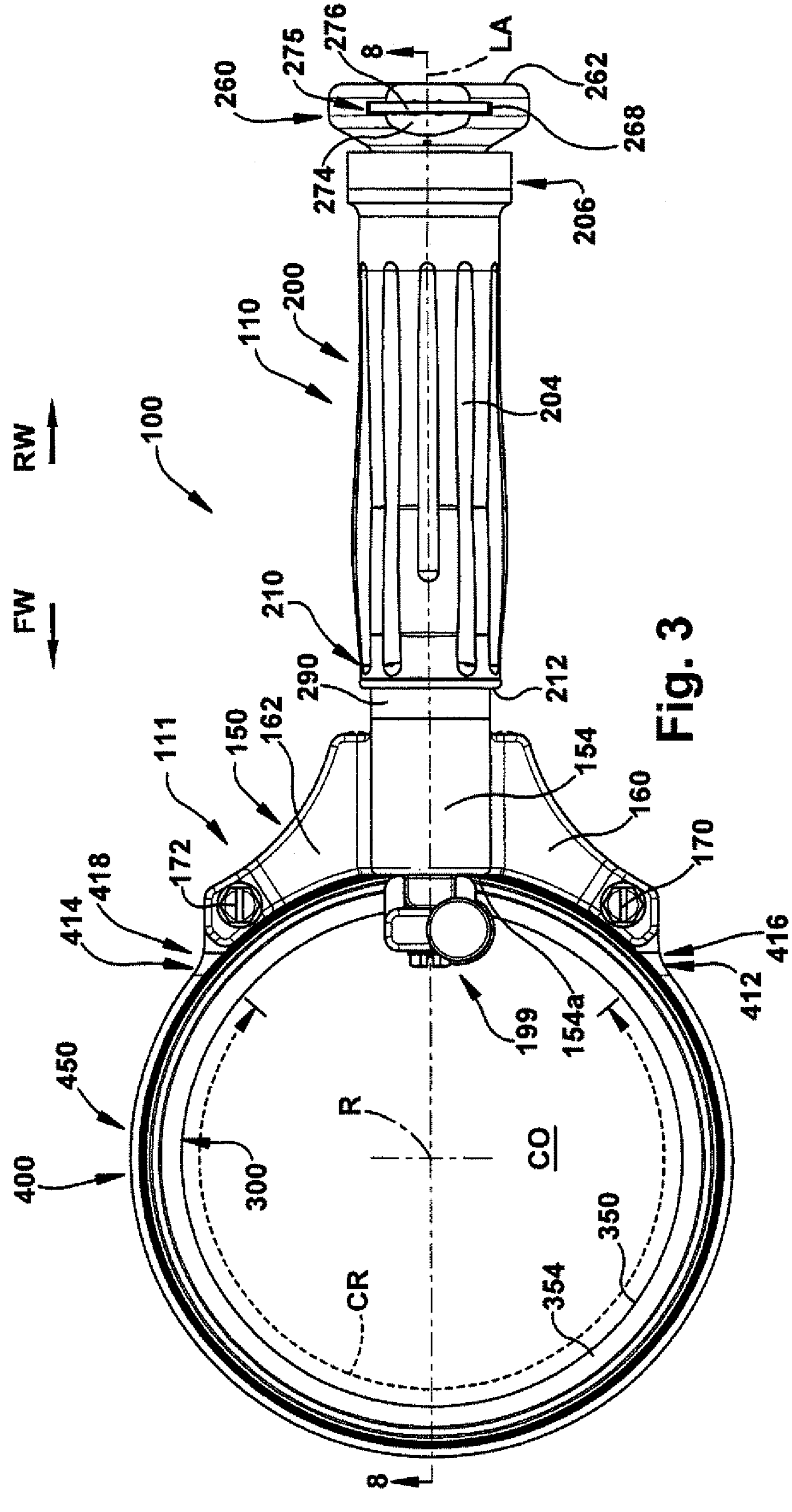
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Fig. 3

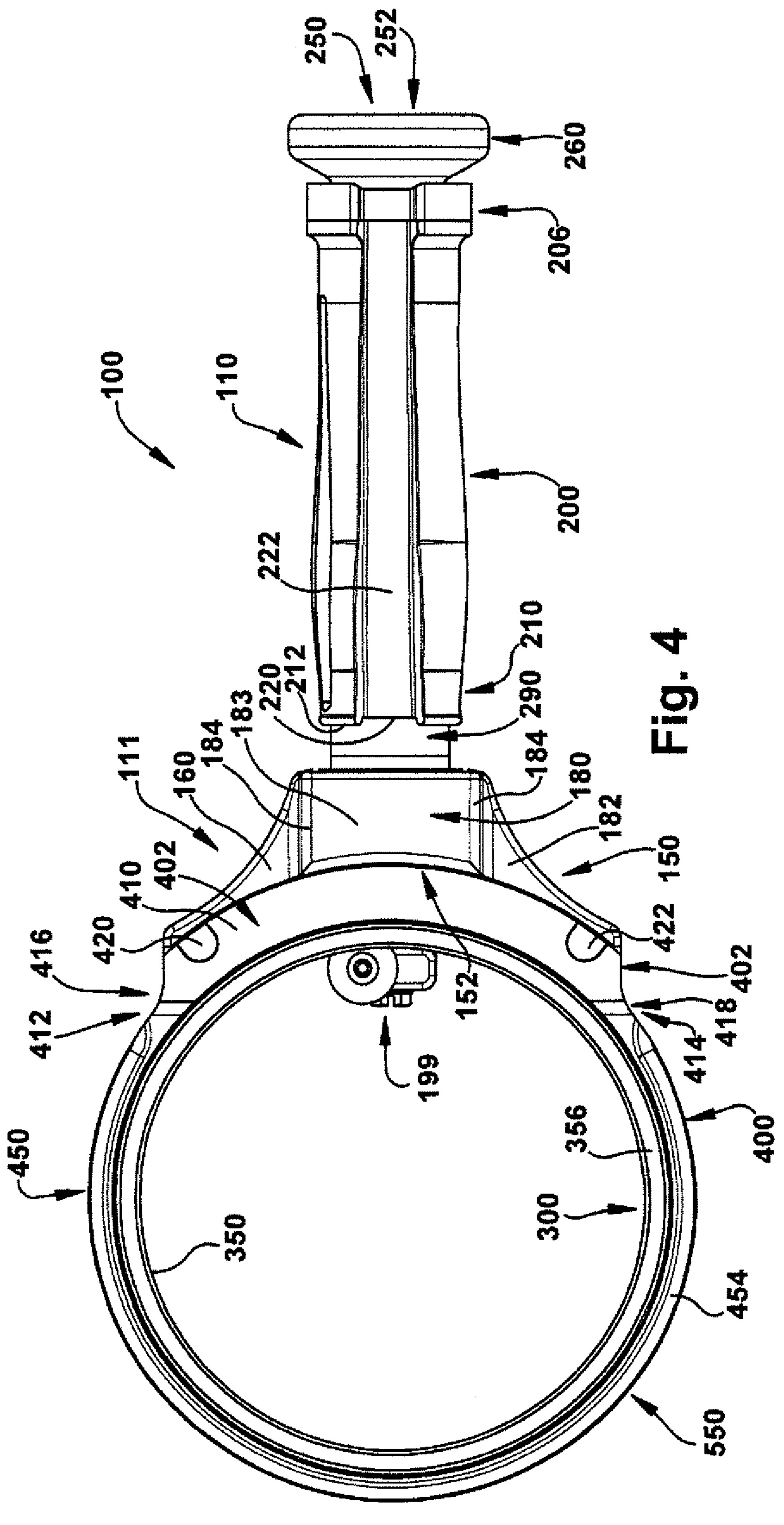
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Fig. 4

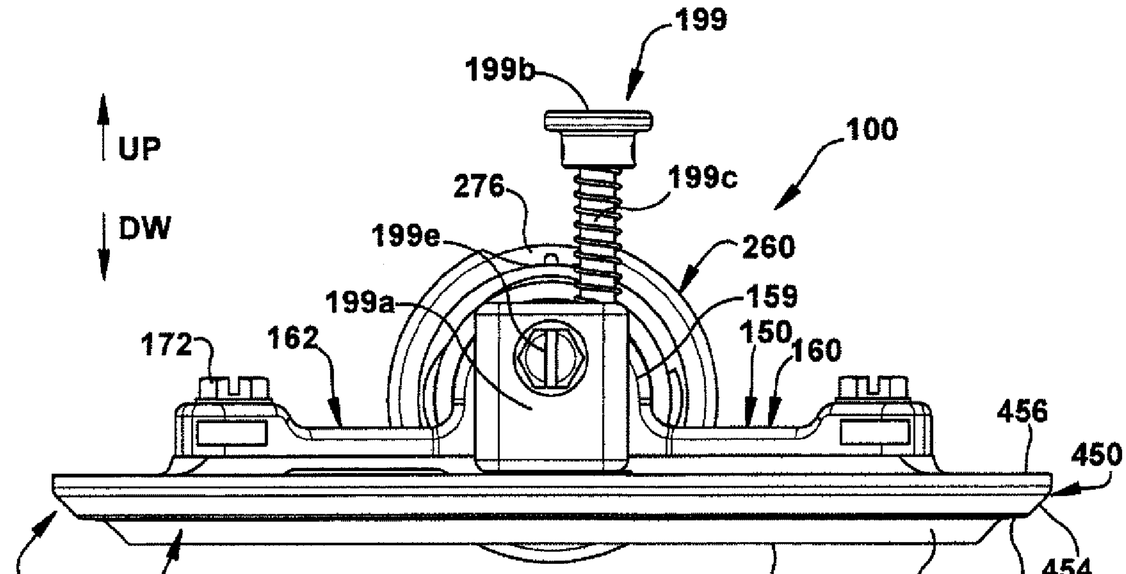
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Fig. 5

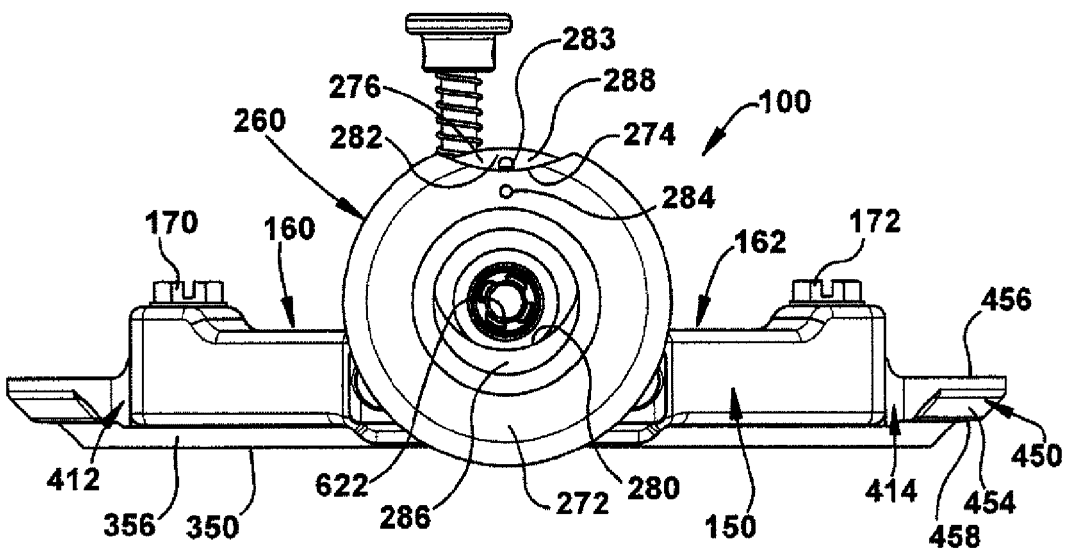
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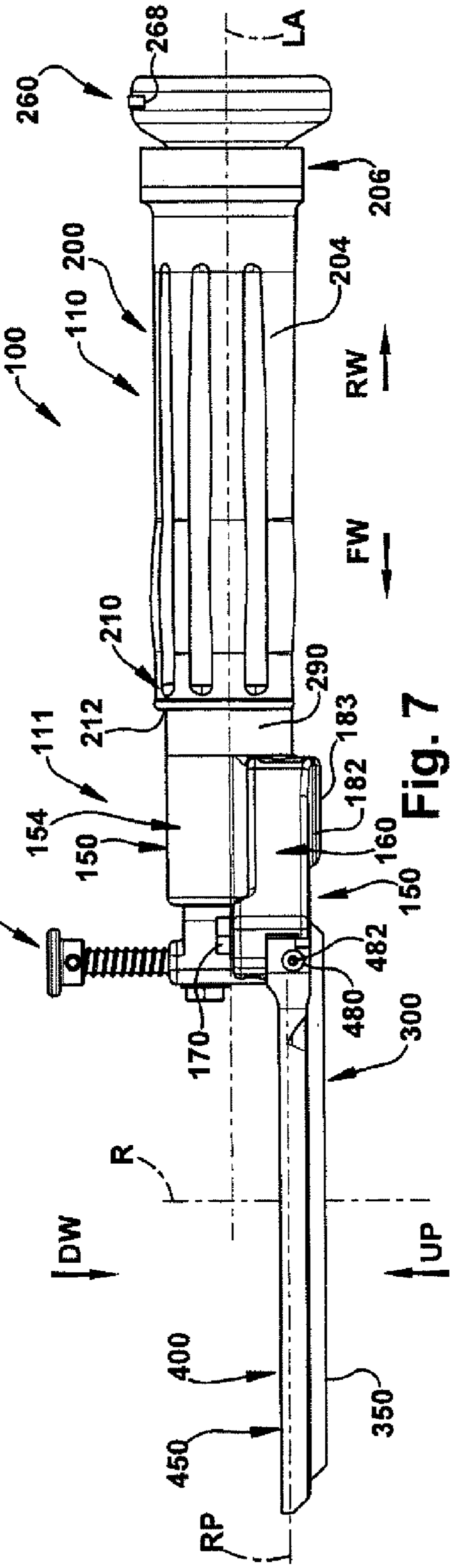
Fig. 6



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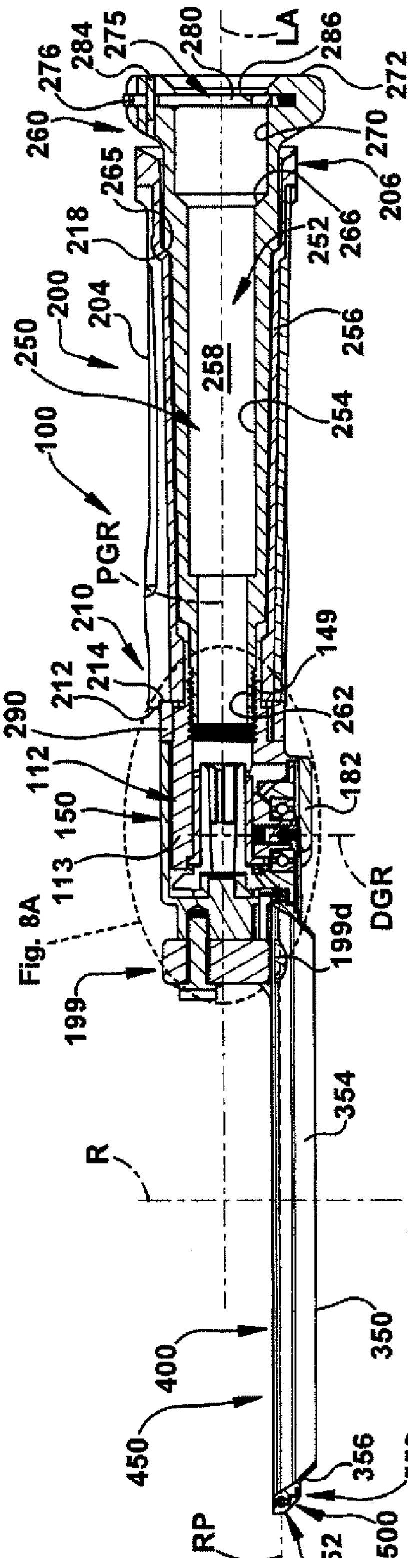

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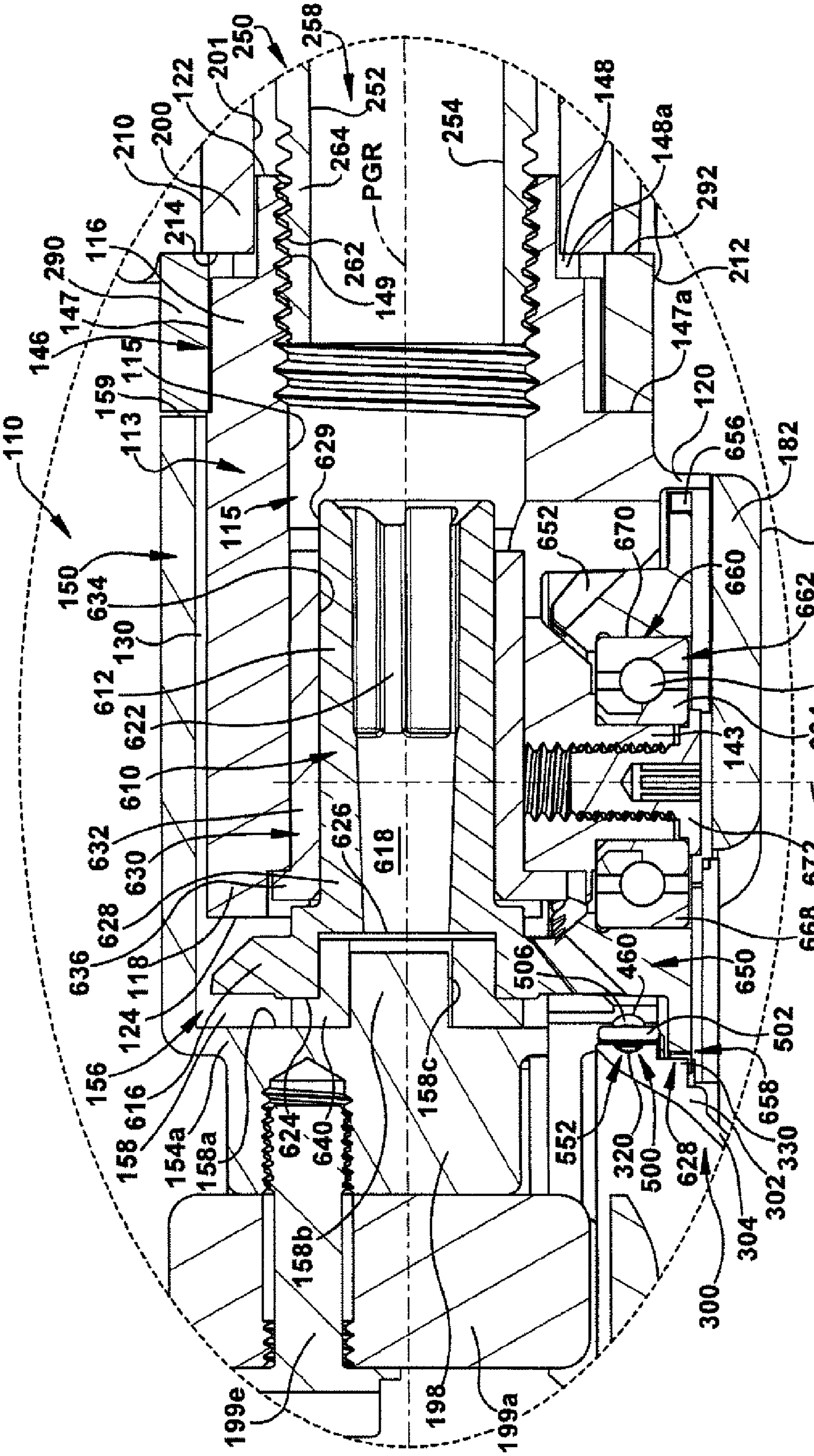
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Fig. 8A

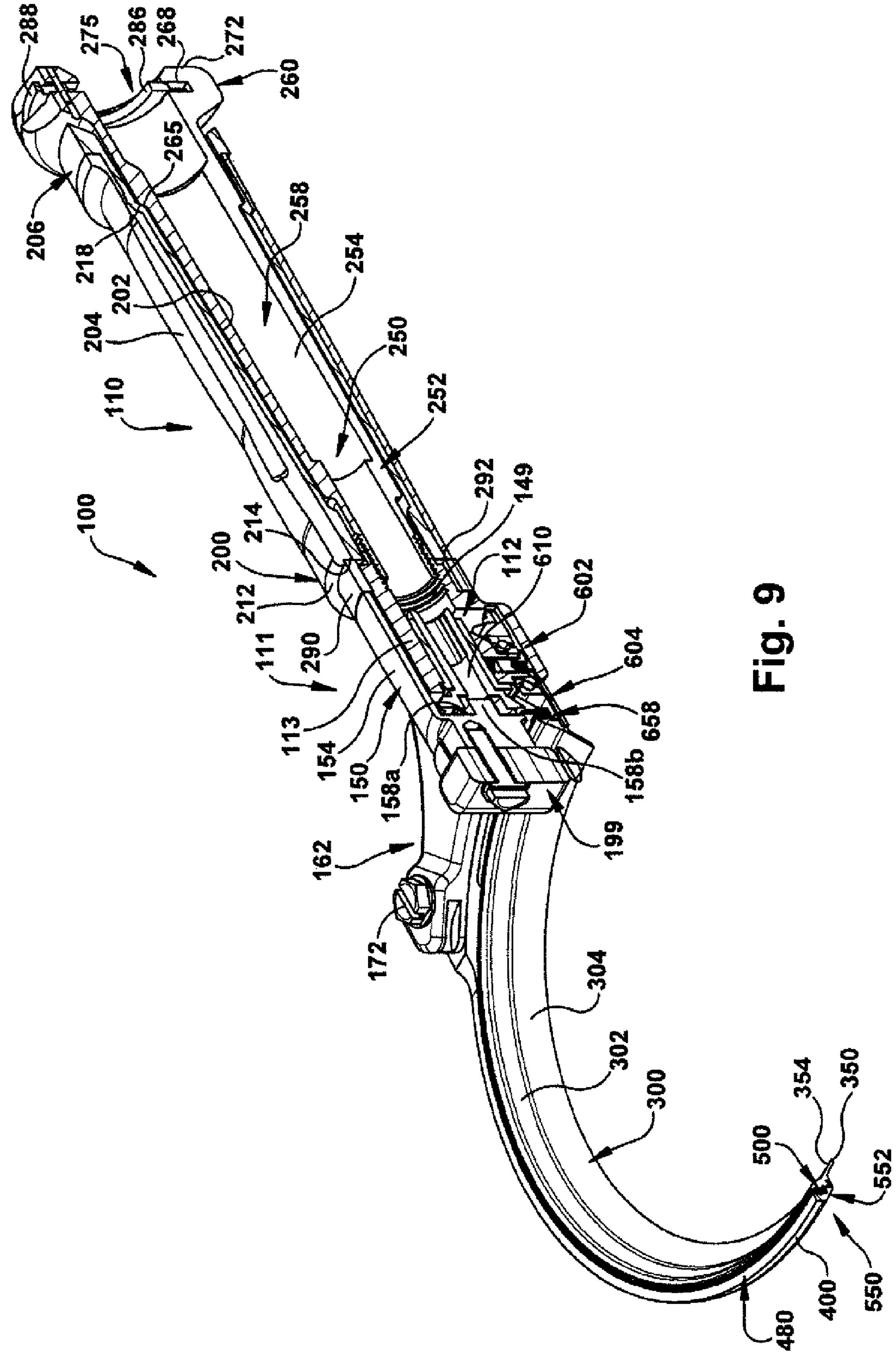

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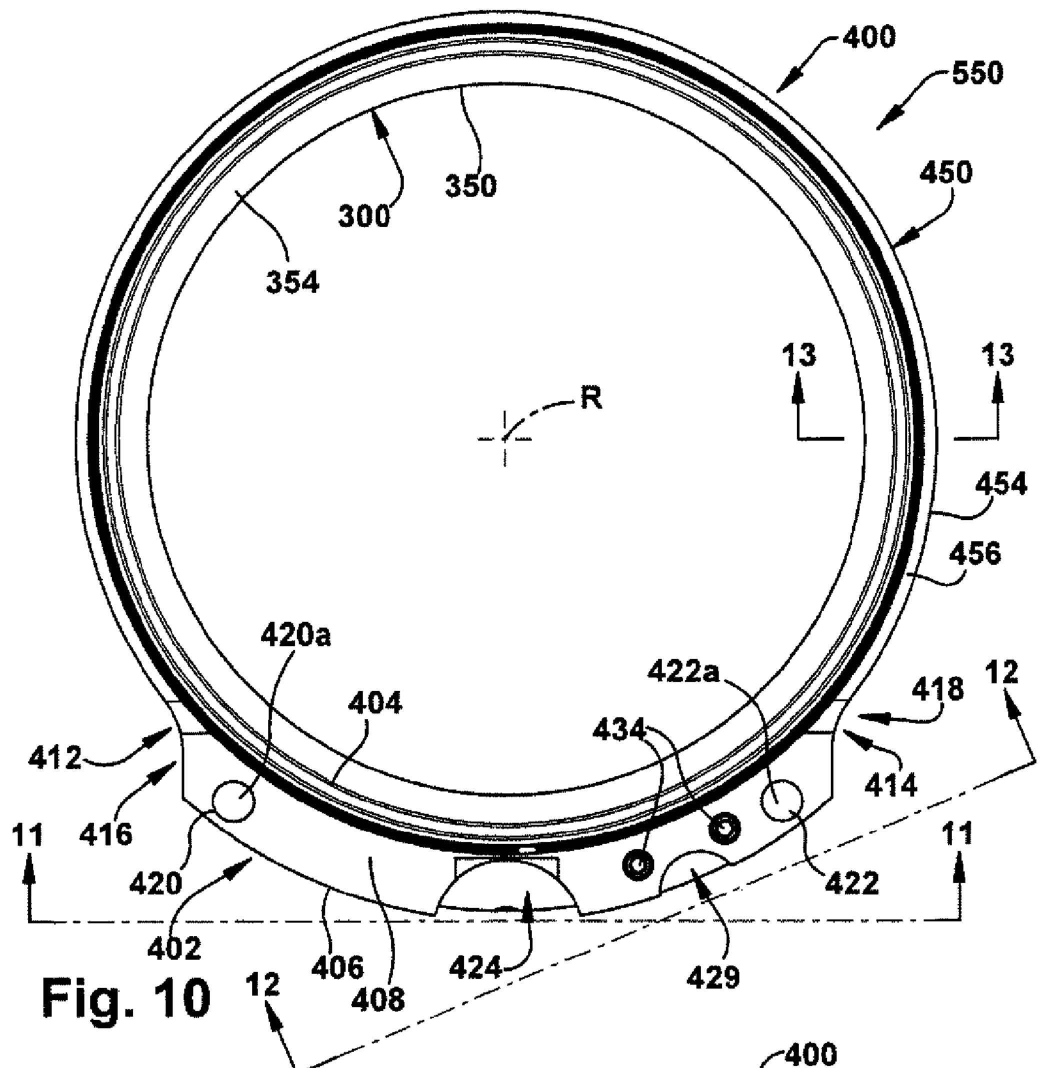
Fig. 9



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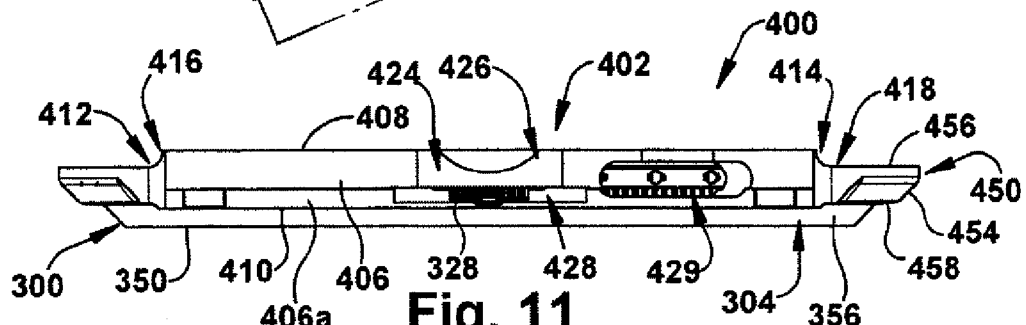

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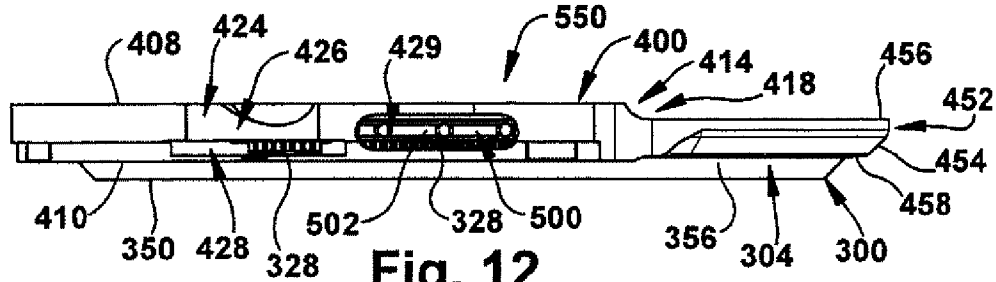

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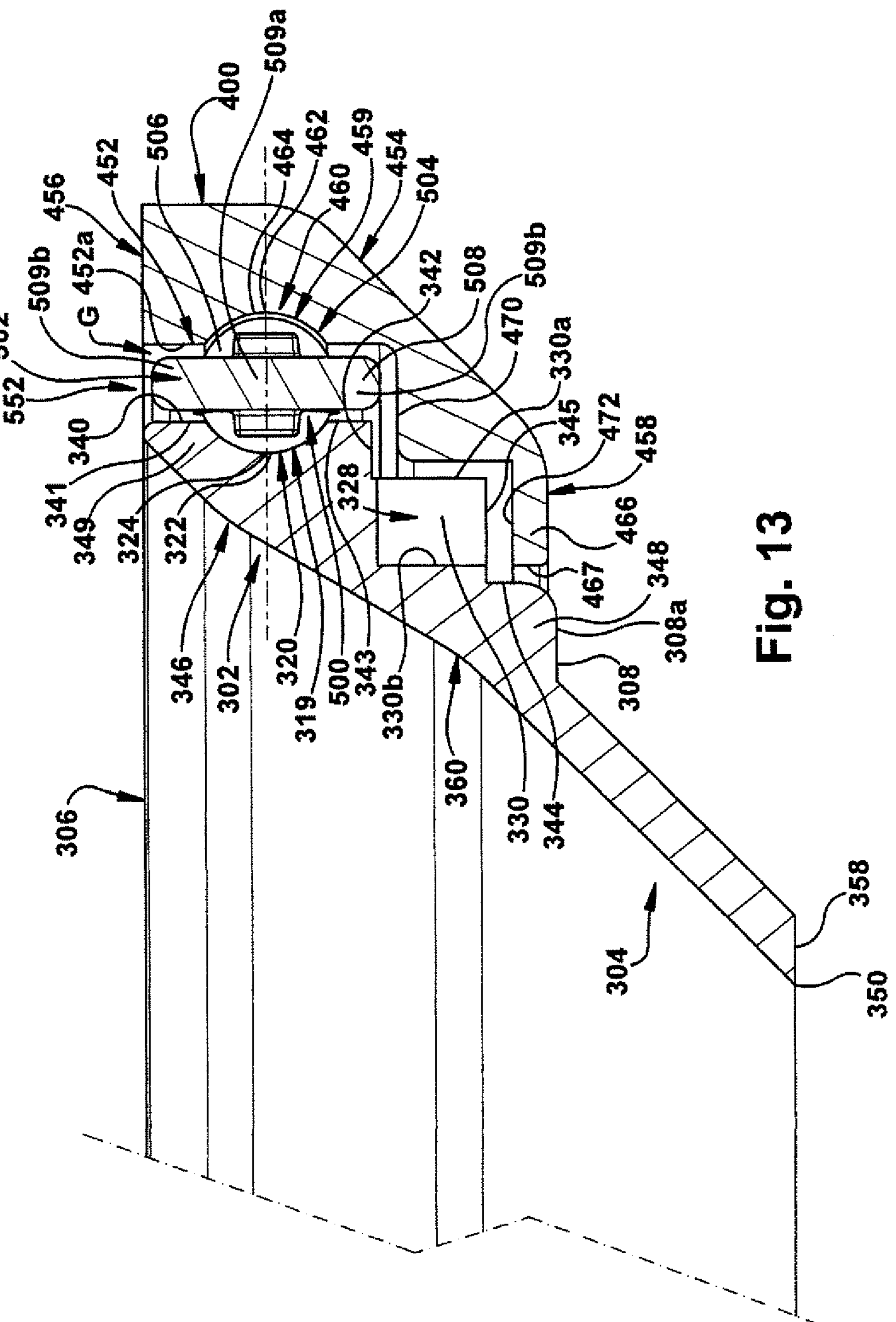

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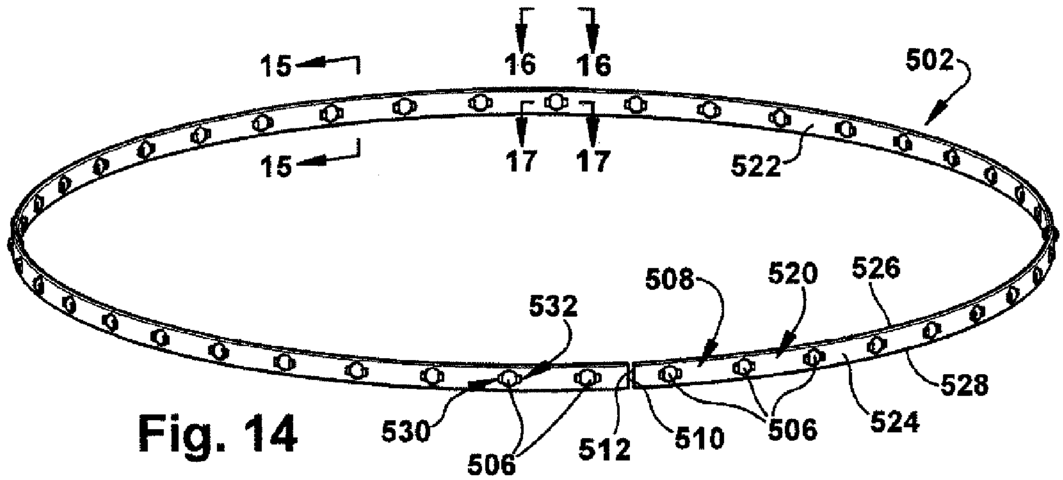

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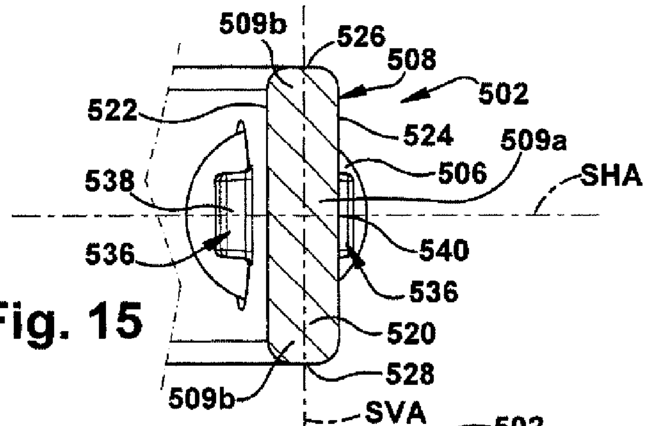

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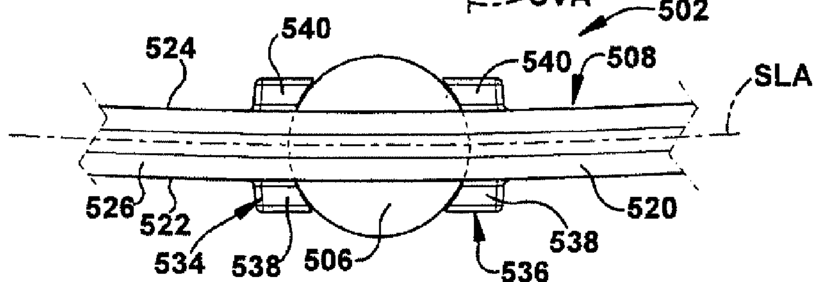

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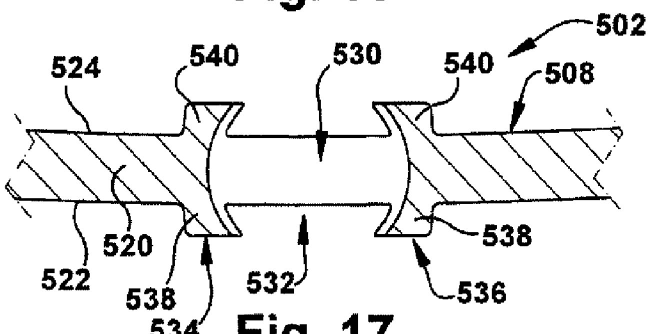

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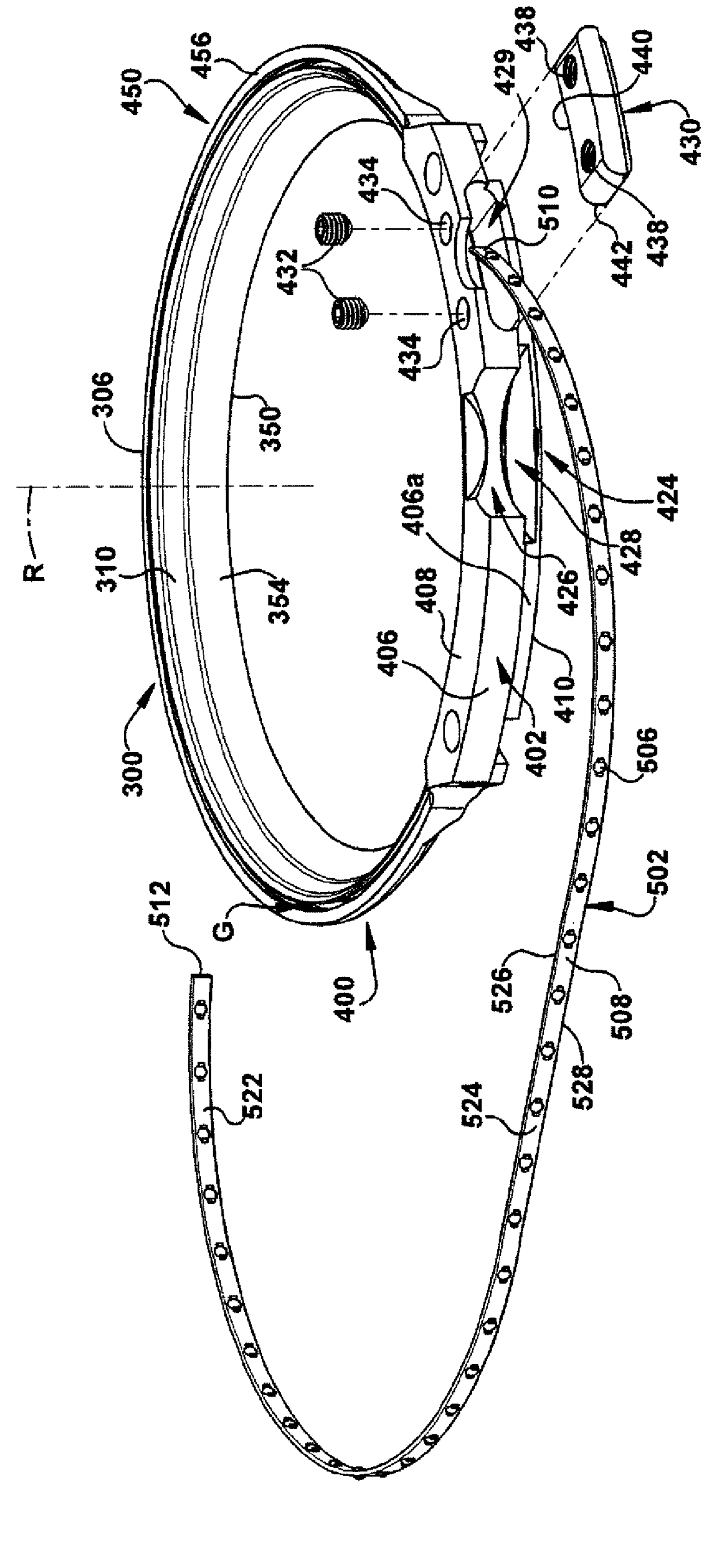
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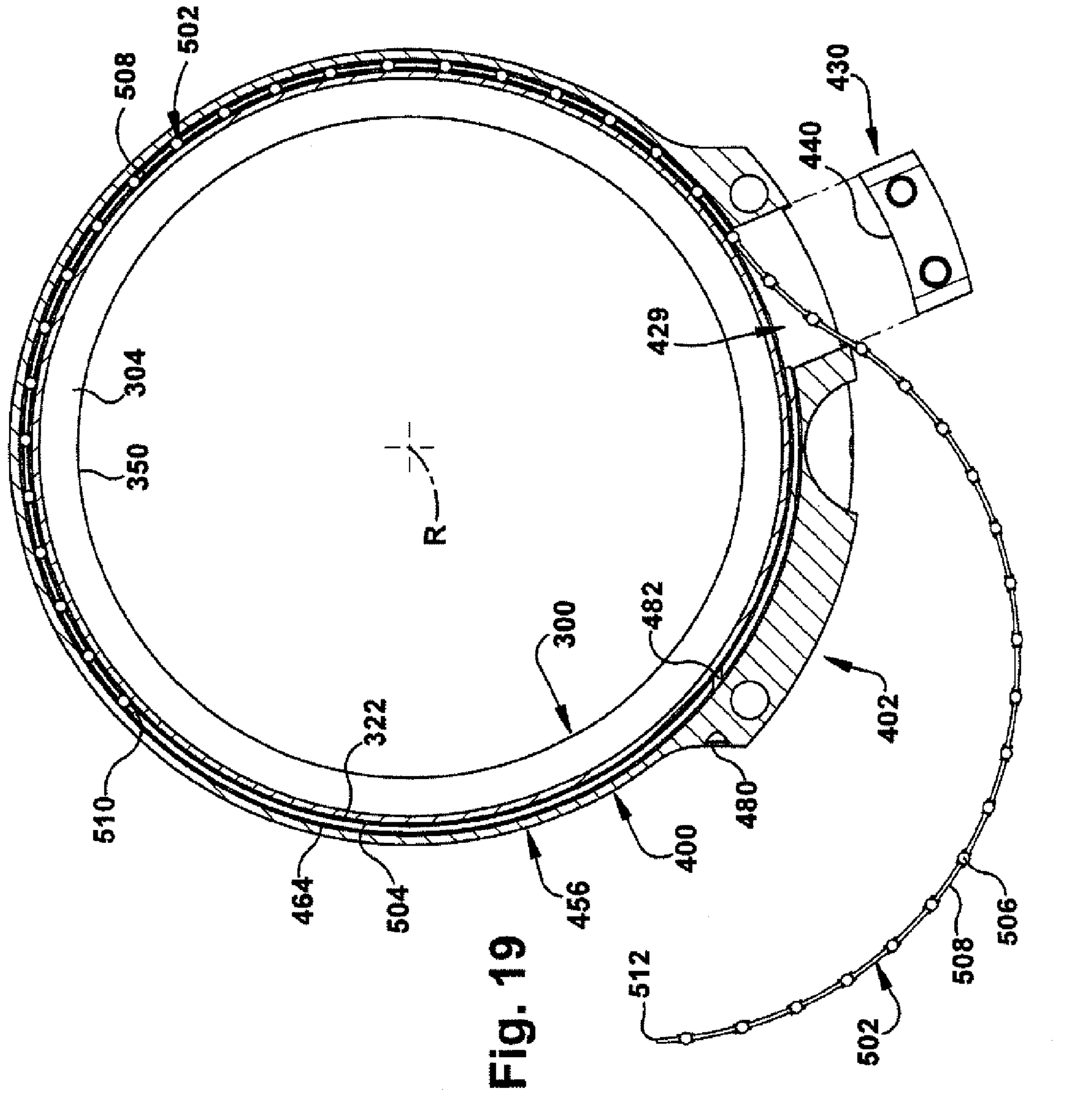
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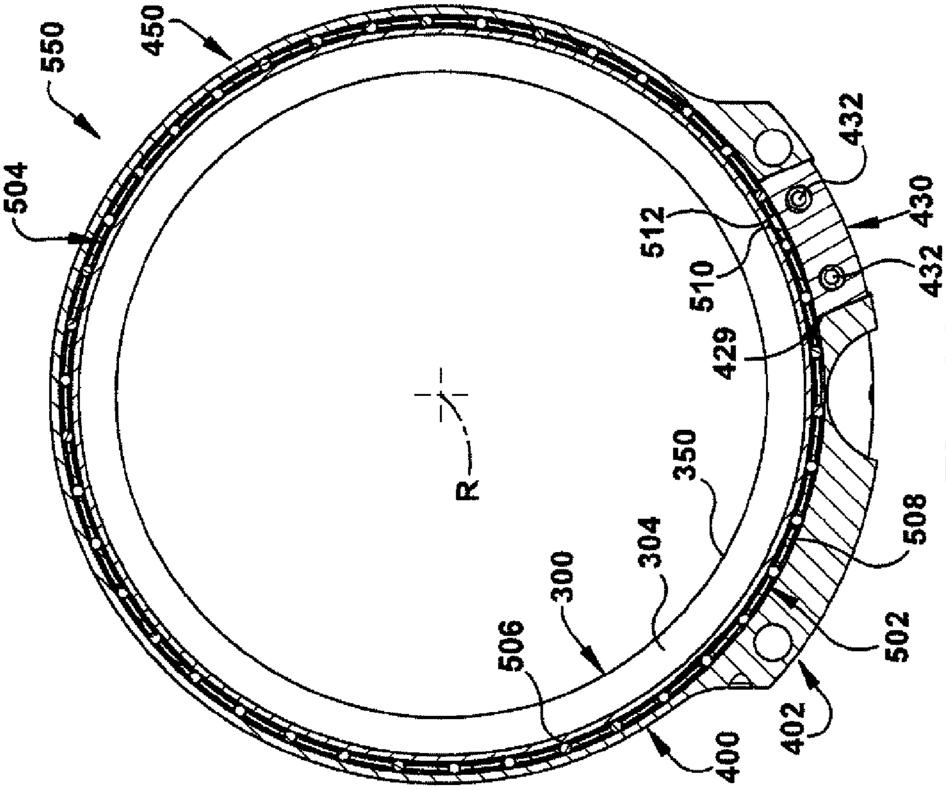
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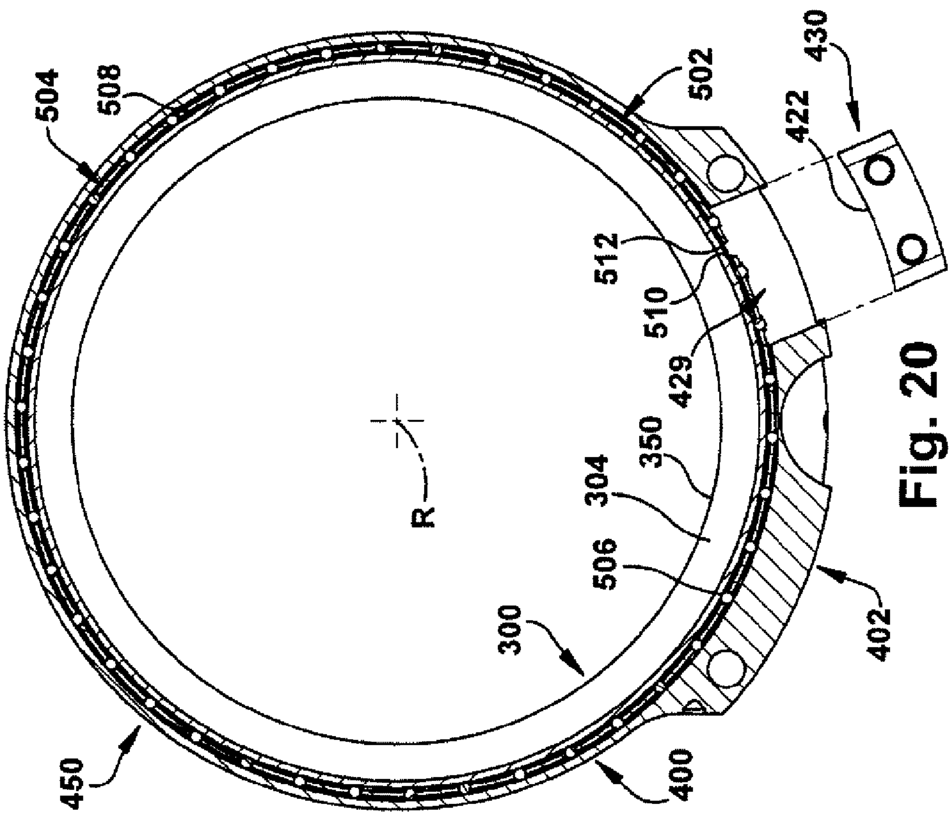
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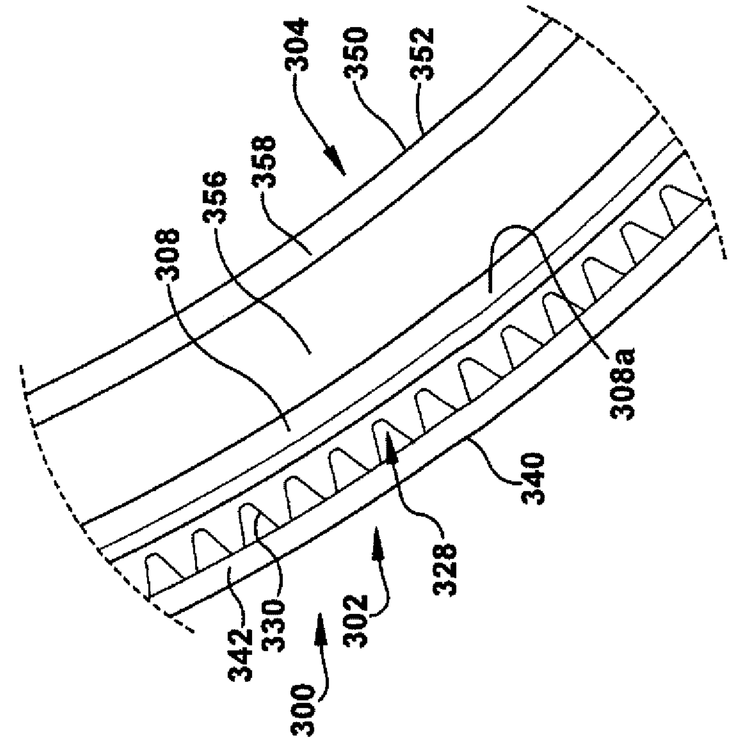
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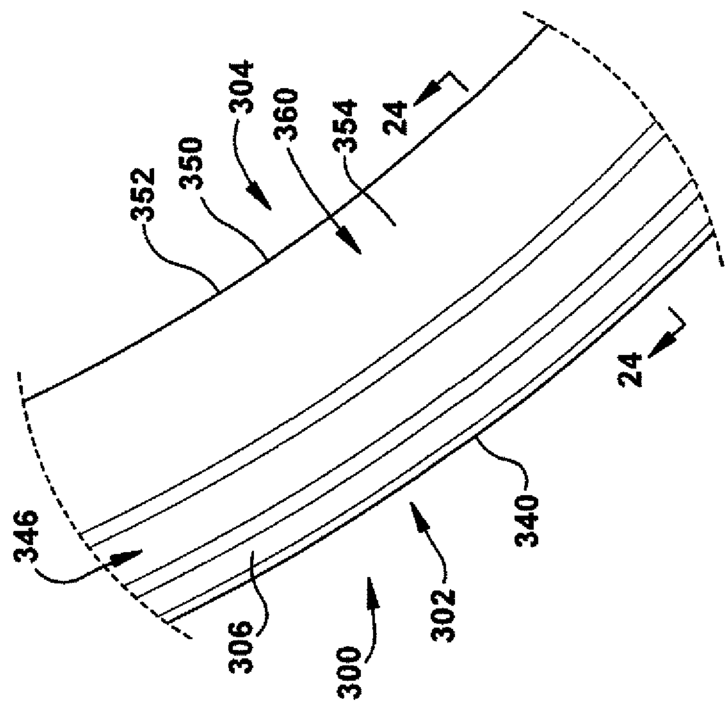
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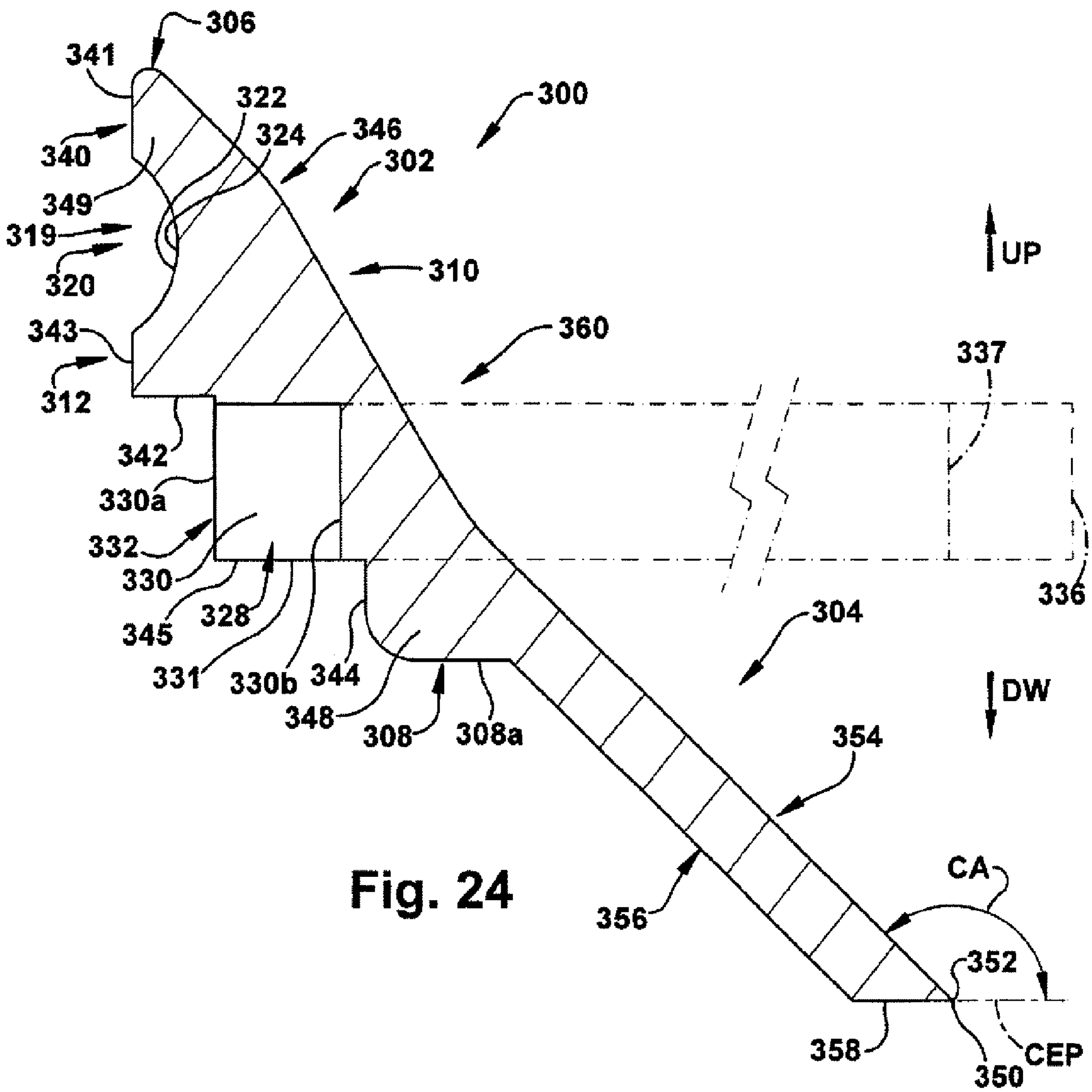
300
302
340

Fig. 22



306
341
300
322
324
346
302
340
349
319
320
310
UP
343
360
312
337
342
330a
332
330
345
328
331
330b
344
348
308
308a
336
304
DW
354
356
CA
352
358
350
CEP

Fig. 24

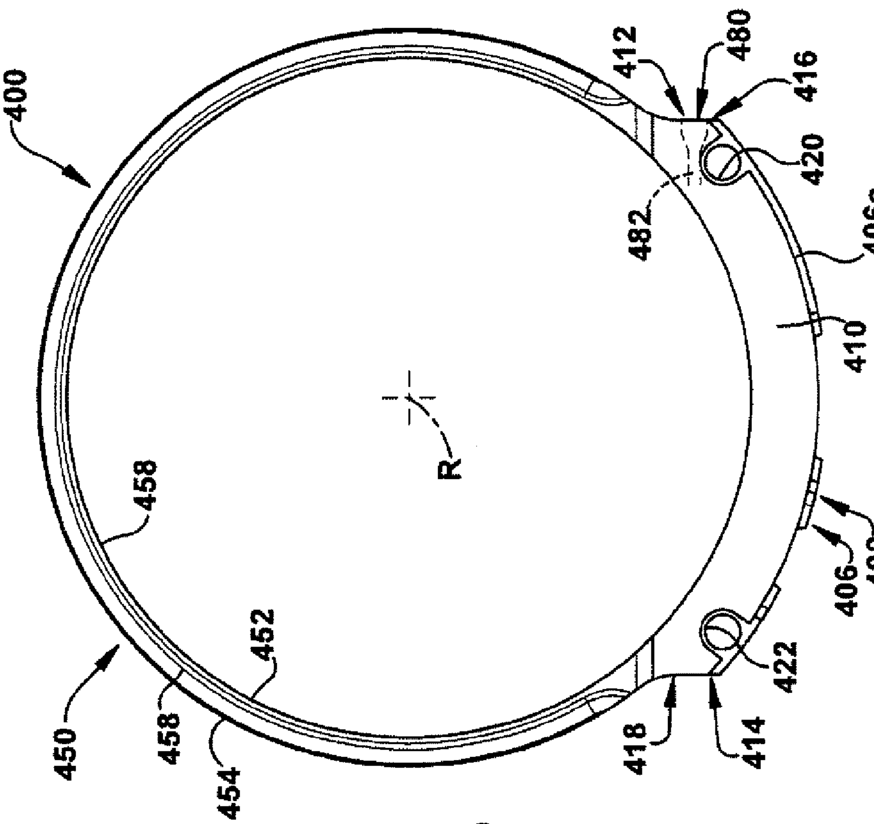
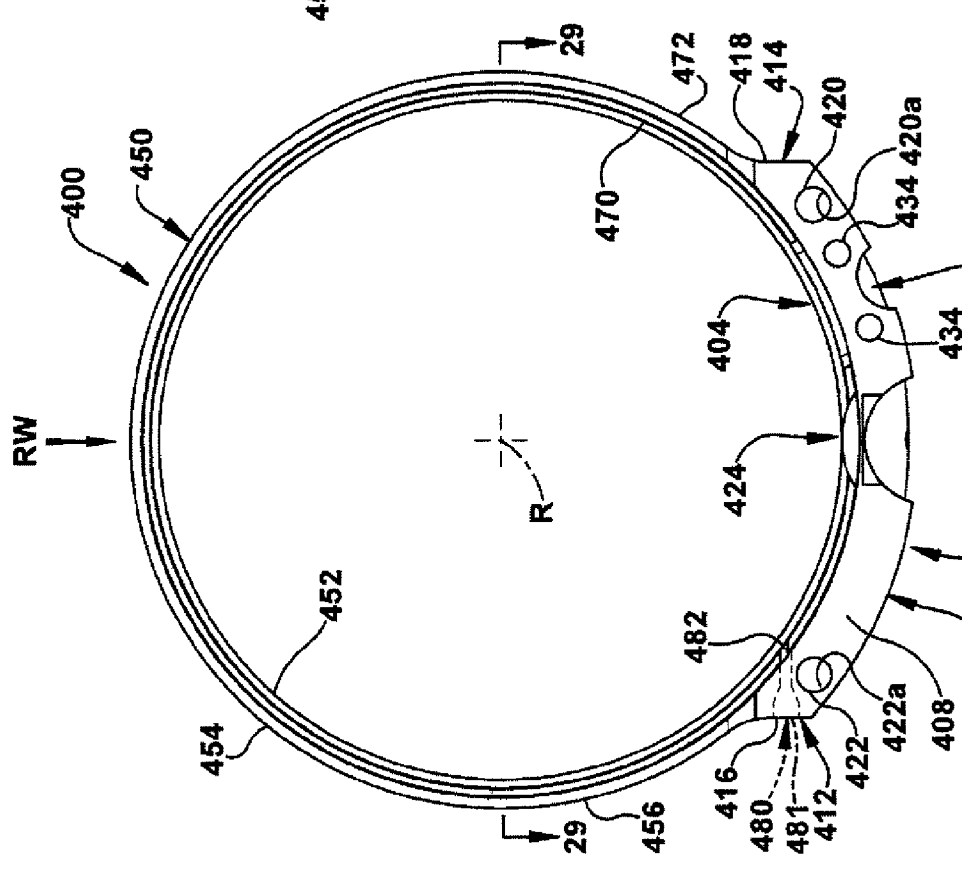

400
412
480
416
420
482
406a
410
R
458
402
406
422
452
450
458
454
418
414

Fig. 26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472
418
414
420
420a
434
400
450
470
429
404
434
RW
424
R
452
482
402
406
454
408
422a
422
416
480
481
412
456
29

Fig. 25

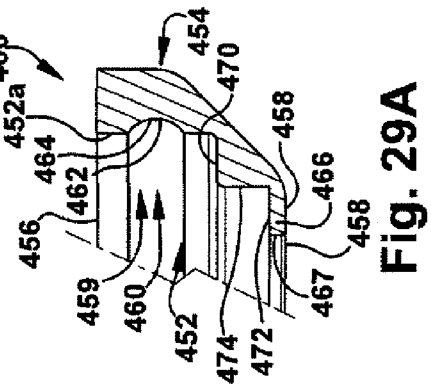


Fig. 29A

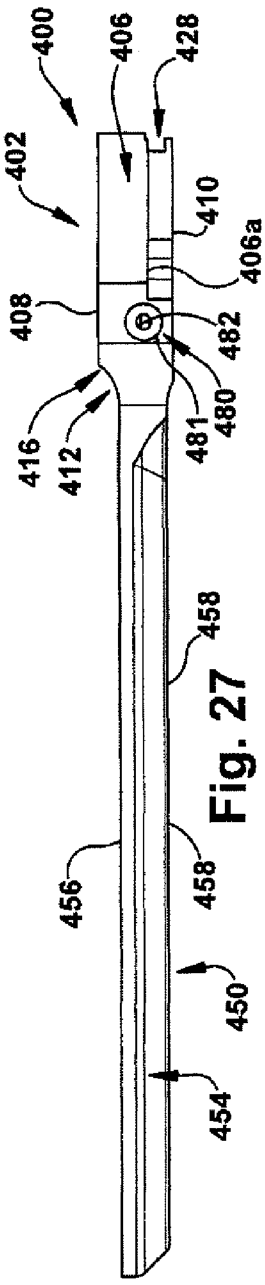


Fig. 27

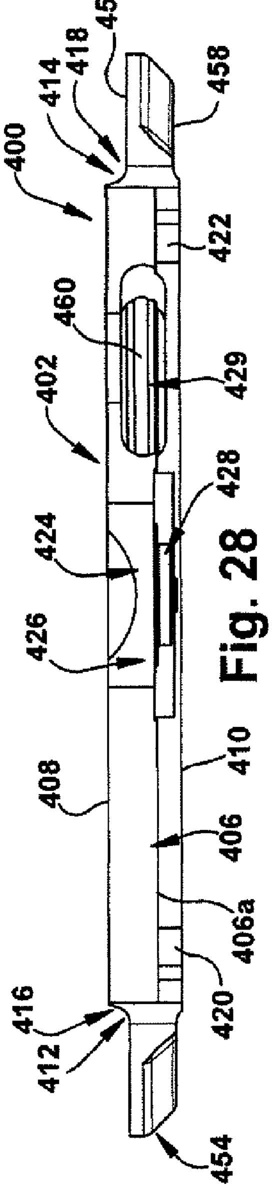


Fig. 28

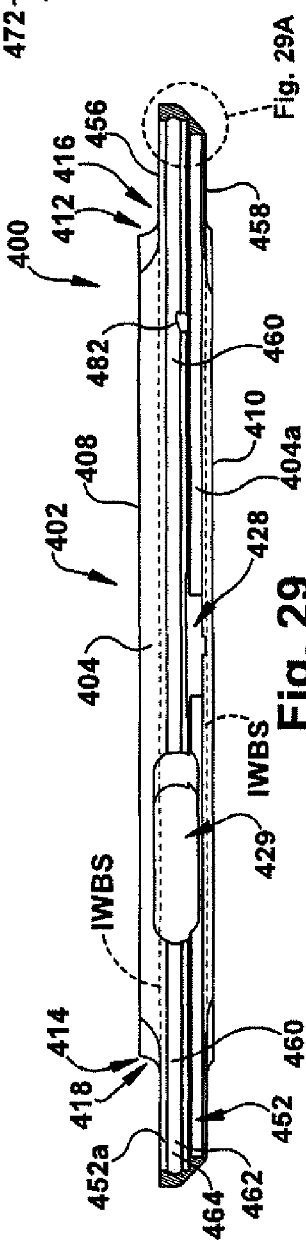


Fig. 29

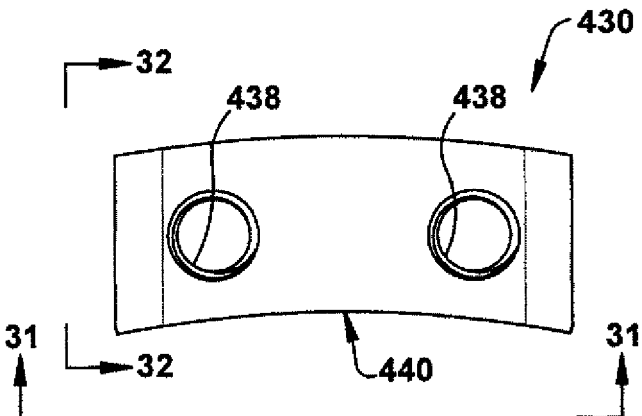


Fig. 30

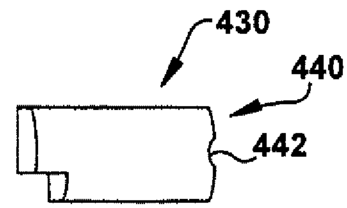


Fig. 32

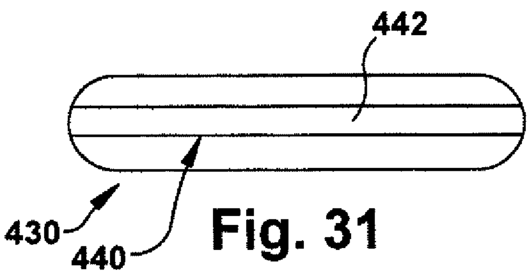


Fig. 31

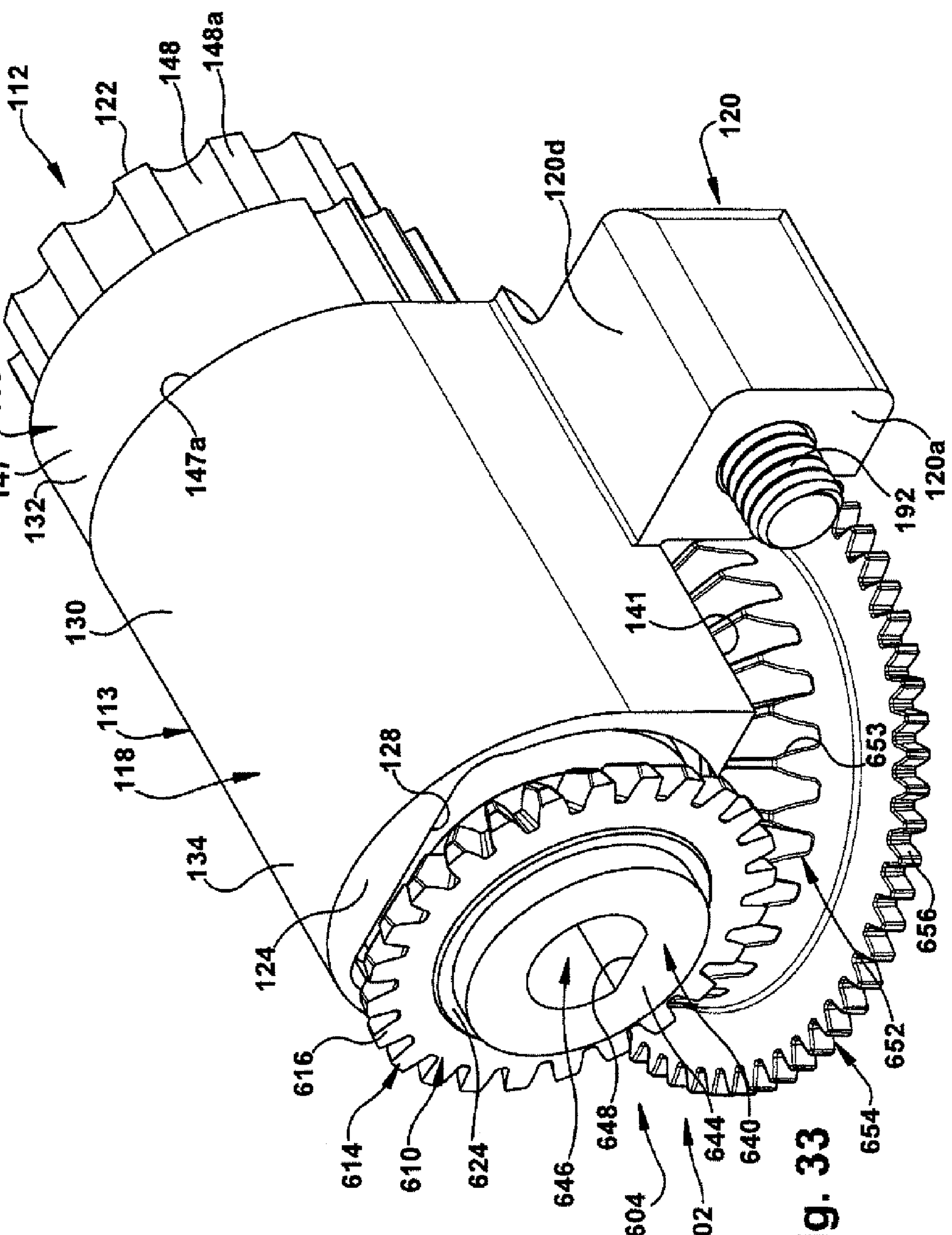
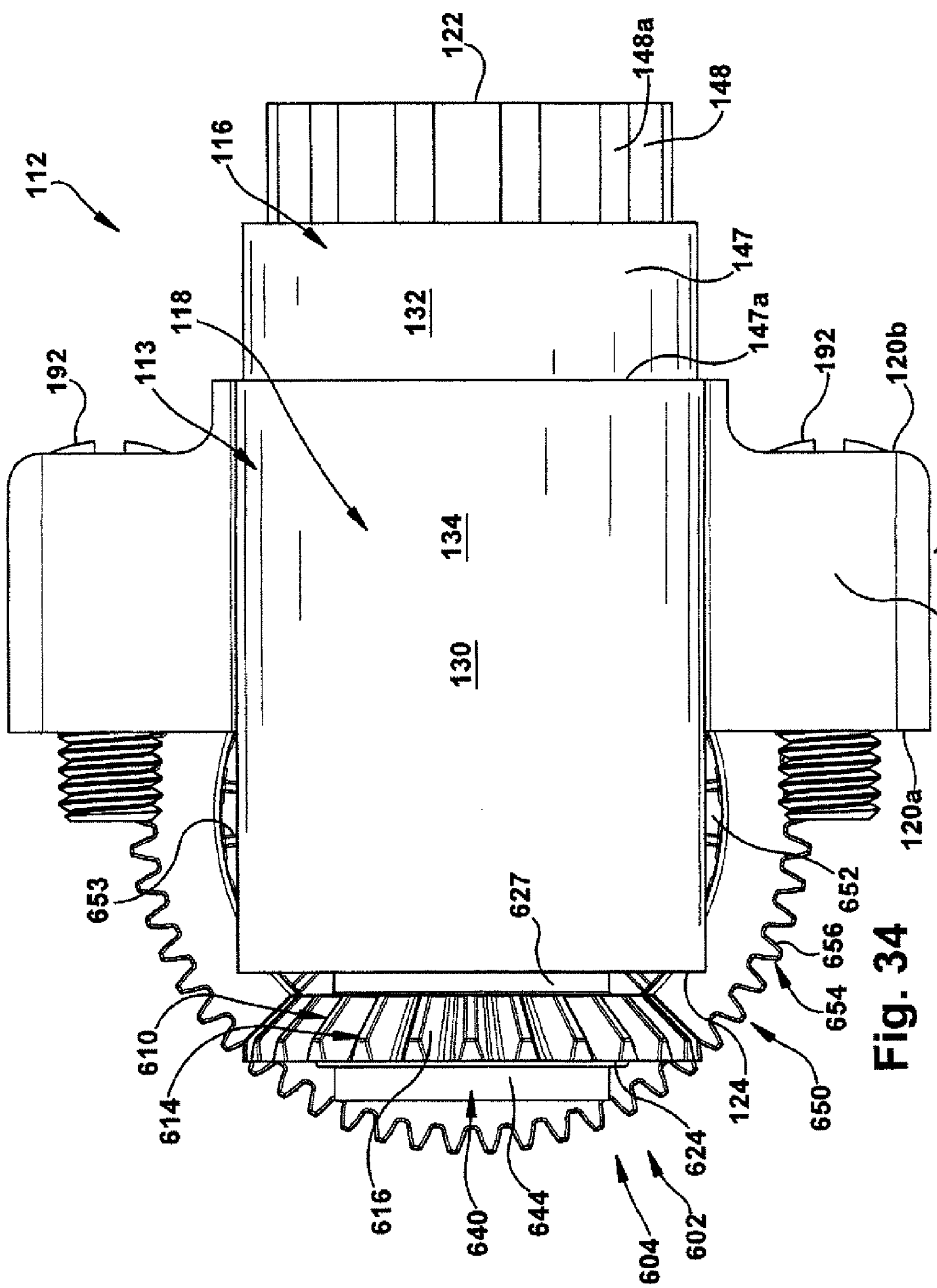

112
122
148
148a
120
120d
116
147
132
147a
192
120a
130
141
113
118
128
653
134
124
656
652
616
614
610
624
646
648
604
602
644
640
654

Fig. 33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122
148a
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116
147
132
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113
192
147a
192
120b
120
134
130
120d
120a
653
652
627
656
654
610
614
616
640
644
604
602
624
124
650

Fig. 34

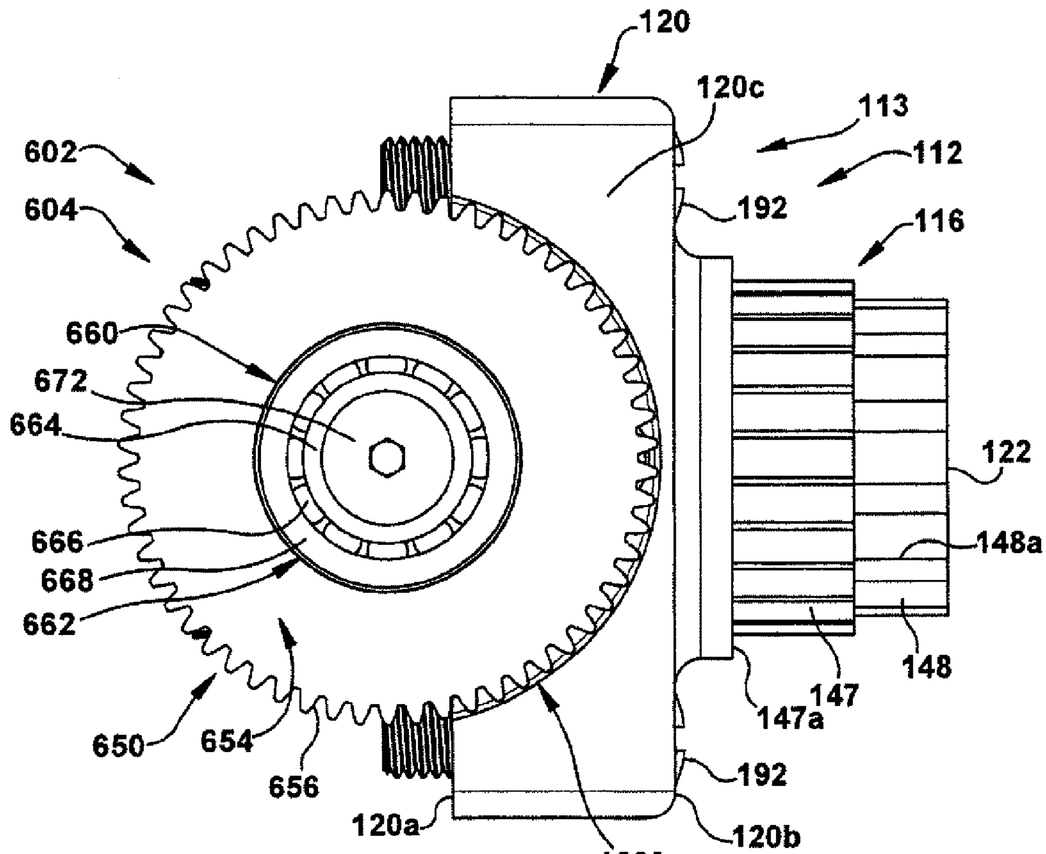

120
120c
113
112
602
604
192
116
660
672
664
122
666
148a
668
662
147
148
147a
650
654
656
192
120a
120b
120f

Fig. 35

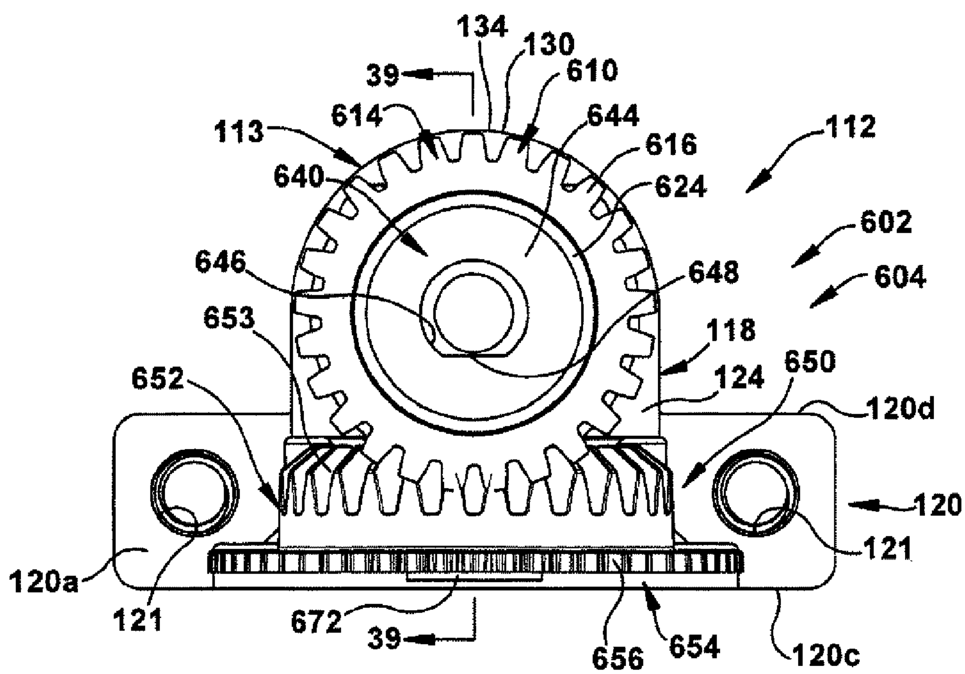
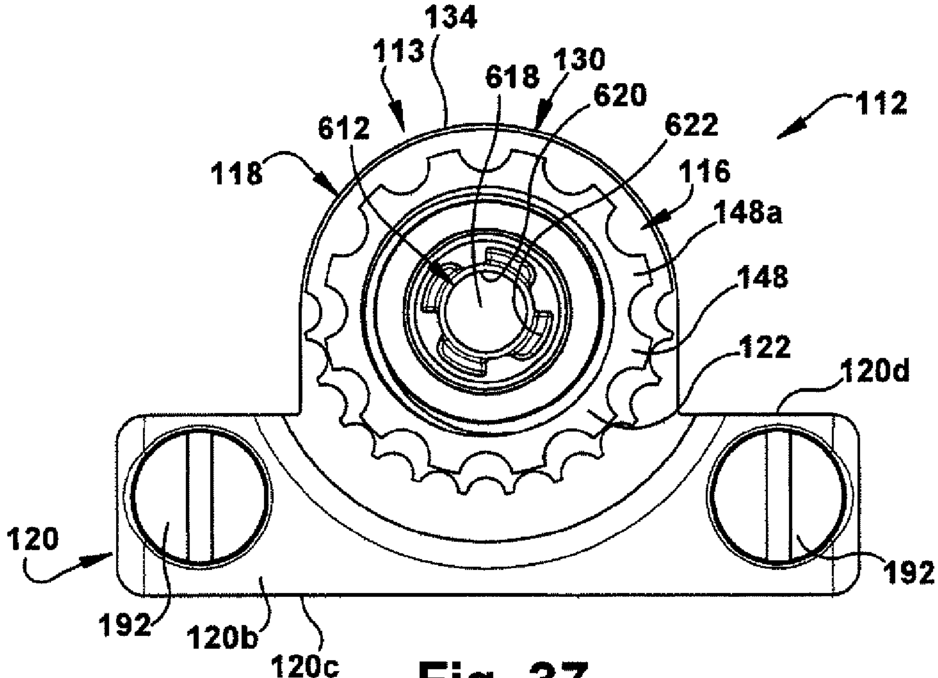

134
130
39
610
614
644
113
616
112
640
624
602
646
648
604
653
118
124
650
652
120d
120
121
120a
121
672
39
656
654
120c

Fig. 36


134
113
130
618
620
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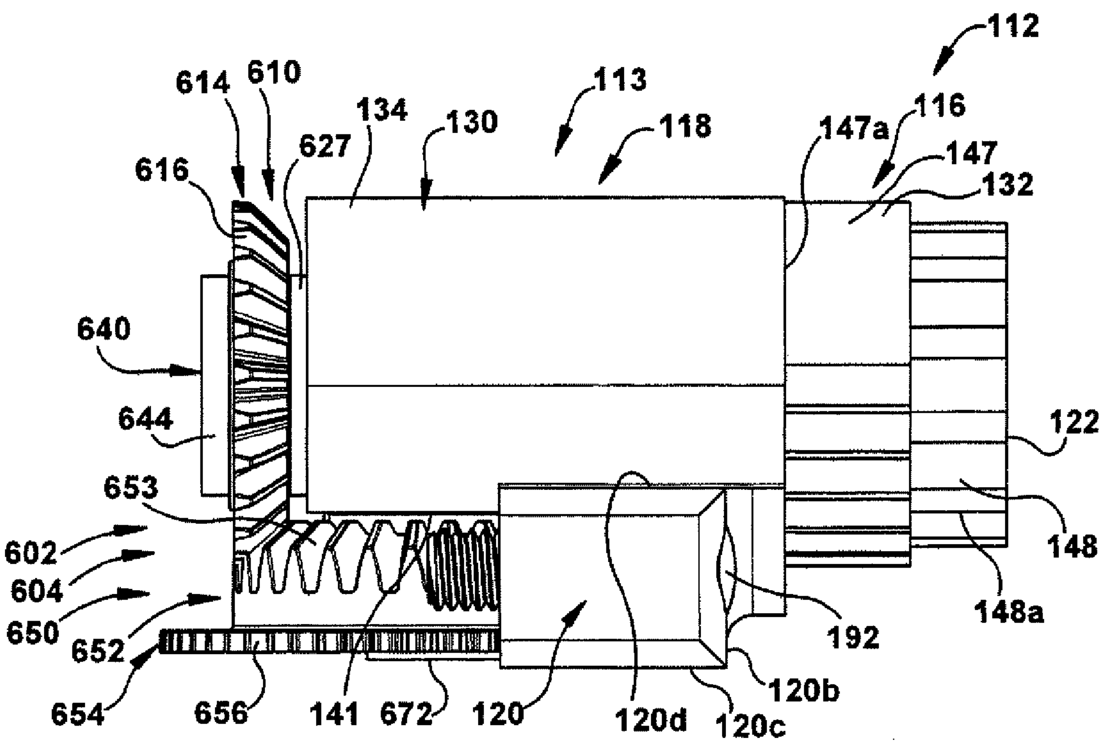
622
112
118
116
148a
148
122
120d
120
192
192
120b
120c

Fig. 37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614
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113
134
130
118
627
116
147a
147
616
132
640
644
122
653
602
604
650
652
148
148a
192
654
656
141
672
120
120d
120c
120b

Fig. 38

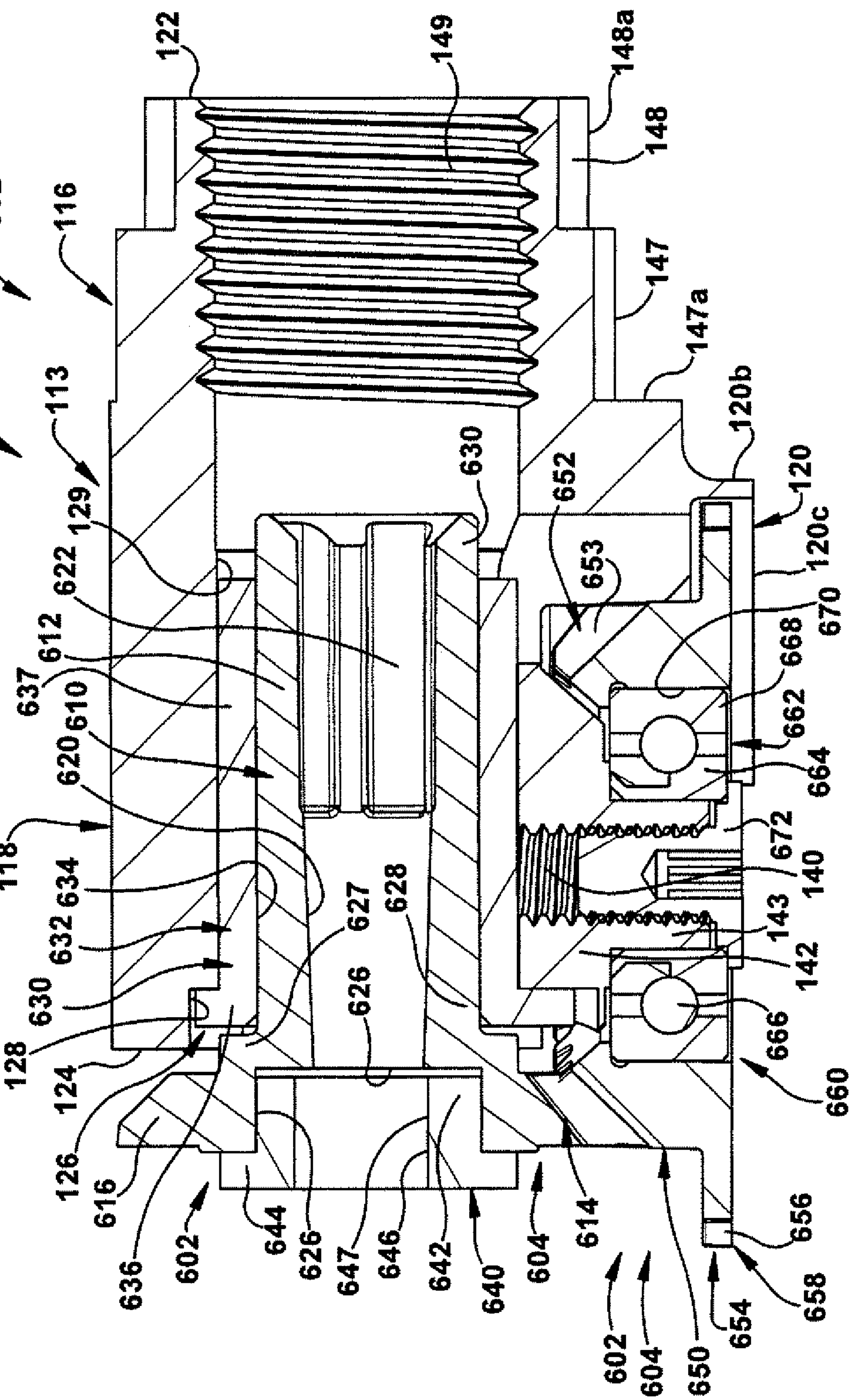
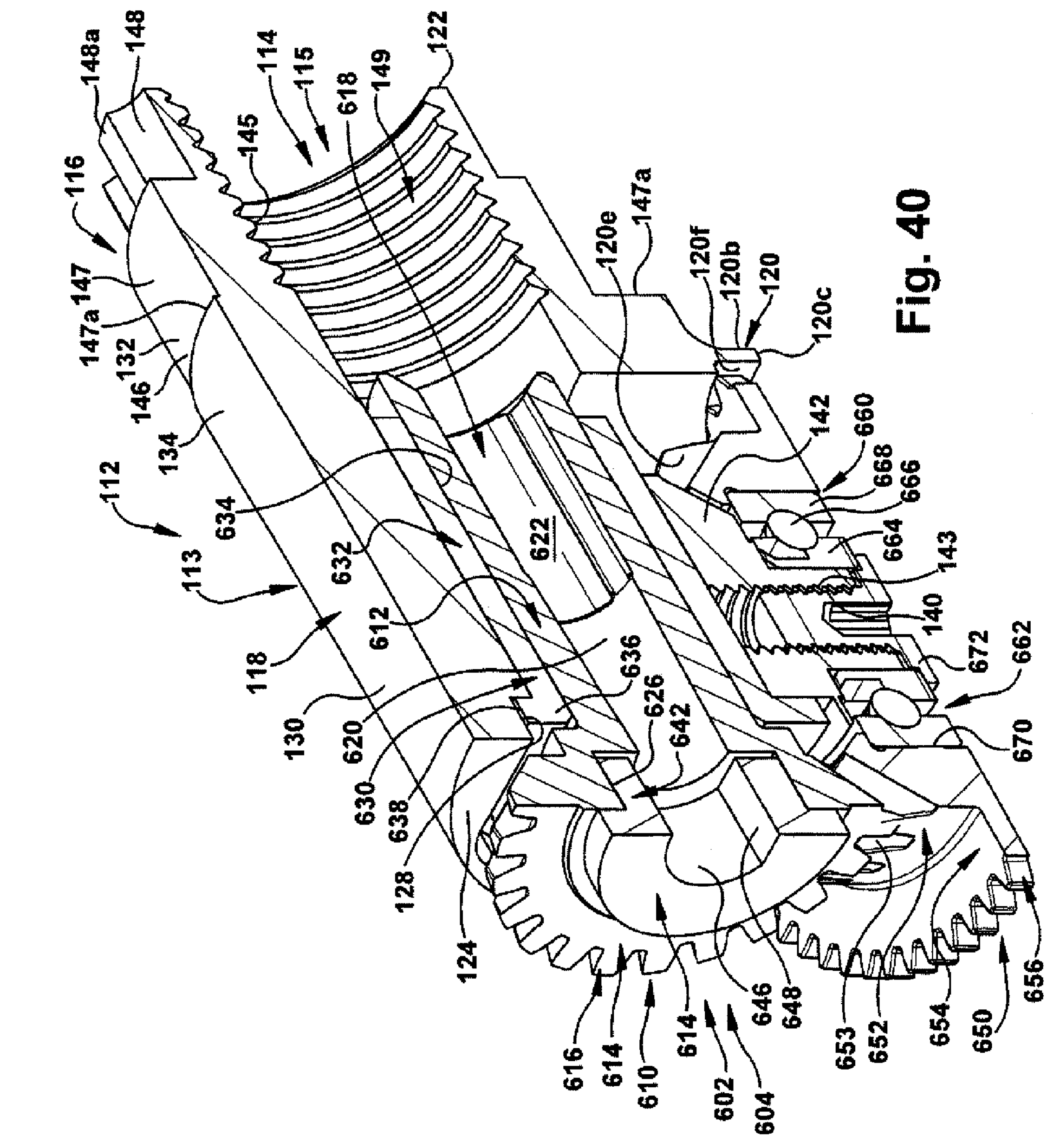

602
116
112
113
122
149
148a
148
147
147a
120b
120
120c
630
652
653
670
668
662
664
672
140
143
142
666
660
129
622
612
637
610
620
118
634
632
630
627
628
626
128
124
126
616
636
602
644
626
647
646
642
640
604
614
602
604
650
654
658
656

Fig. 39


148a
148
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114
115
145
618
149
122
147a
147
132
146
134
112
113
118
130
620
630
638
128
124
634
632
612
622
636
626
642
120e
147a
120f
120b
120
120c
142
660
668
666
664
143
140
672
662
670
616
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614
602
604
646
648
653
652
654
650
656

Fig. 40

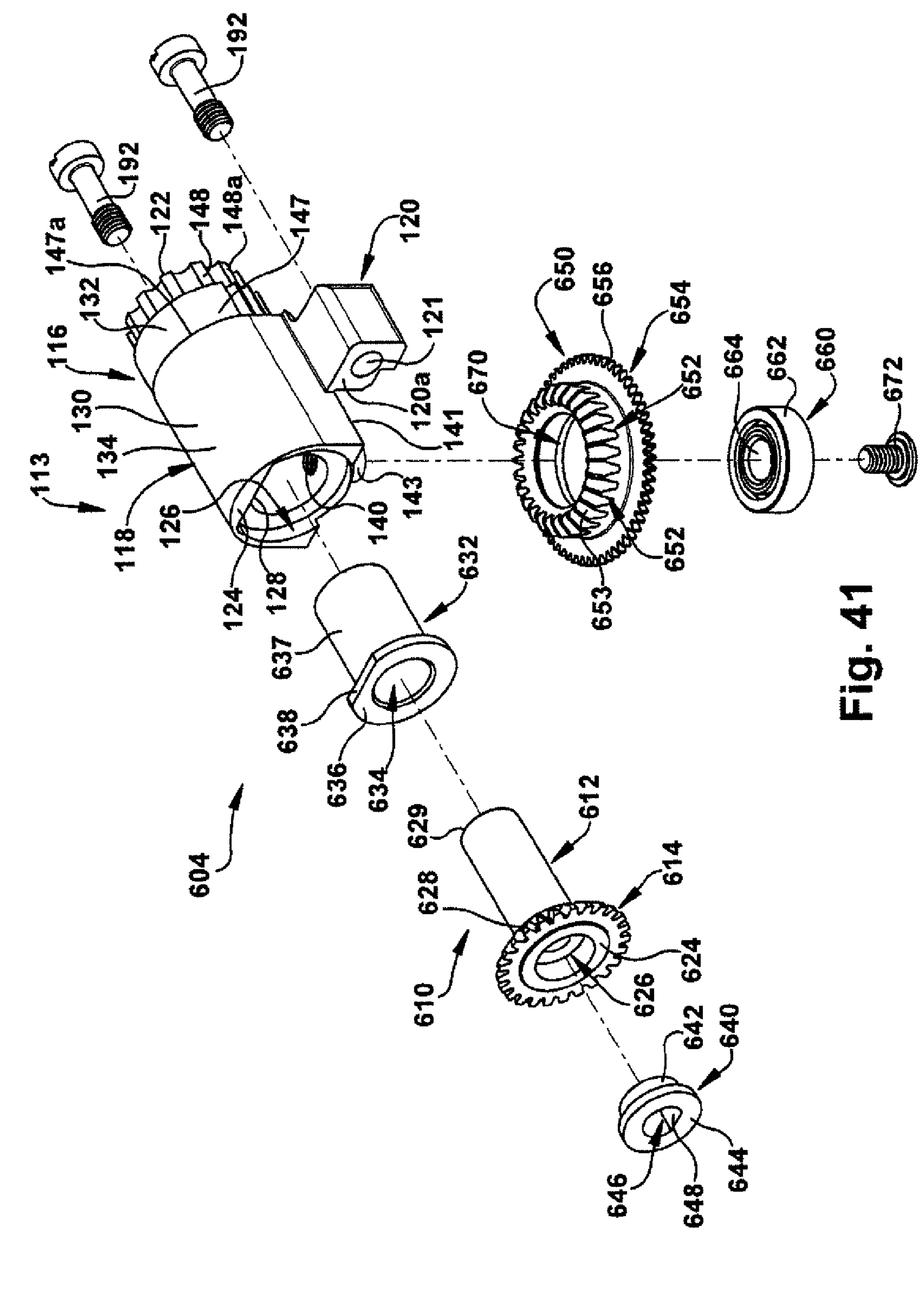

192
192
122
148
148a
147
147a
132
120
121
120a
116
130
134
113
118
126
124
128
140
143
141
650
656
654
670
652
652
652
653
664
662
660
672
632
637
638
636
634
604
612
629
628
614
624
626
610
642
640
646
648
644

Fig. 41

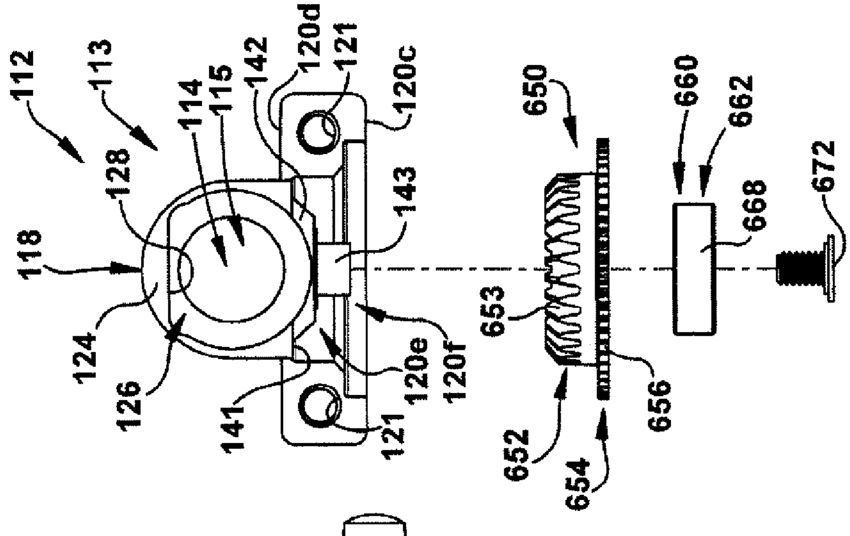

112
113
114
115
118
124
126
128
141
142
143
120c
120d
120e
120f
121
650
652
653
654
656
660
662
668
672

Fig. 43

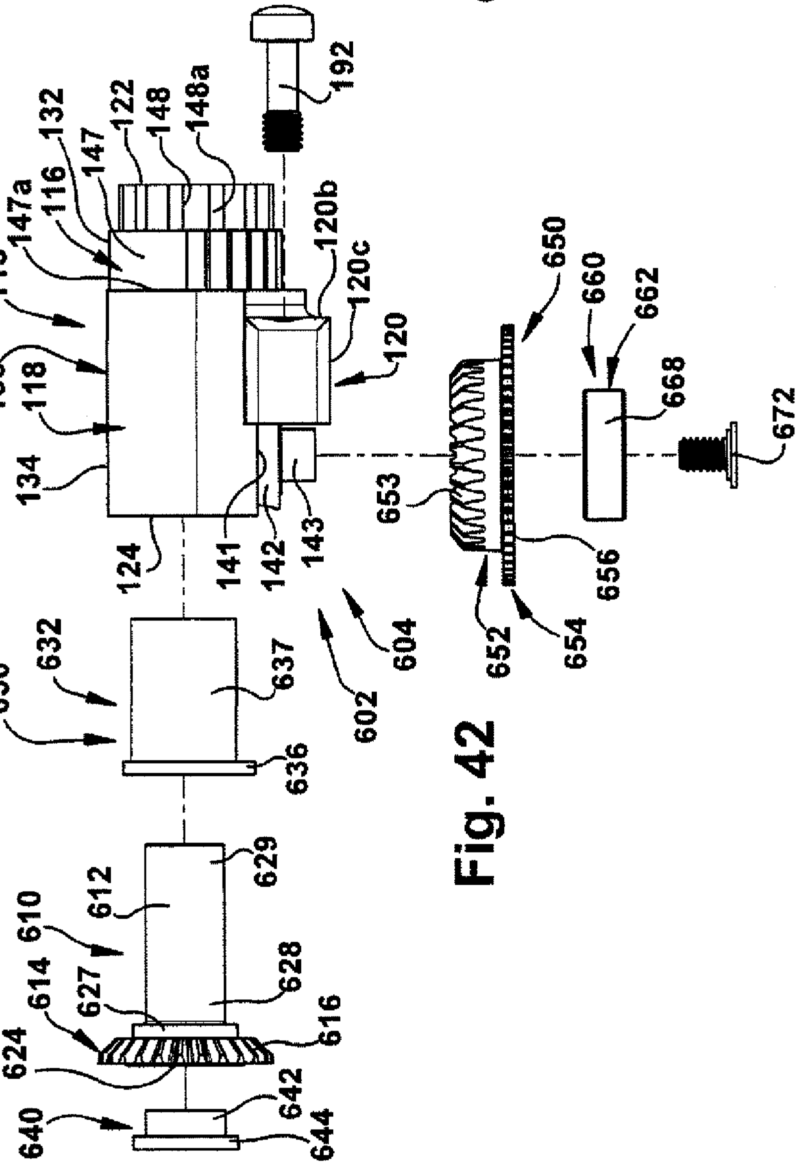

112
113
116
118
120
120b
120c
122
124
130
132
134
141
142
143
147
147a
148
148a
192
602
604
610
612
614
616
624
627
628
629
630
632
636
637
640
642
644
650
652
653
654
656
660
662
668
672

Fig. 42

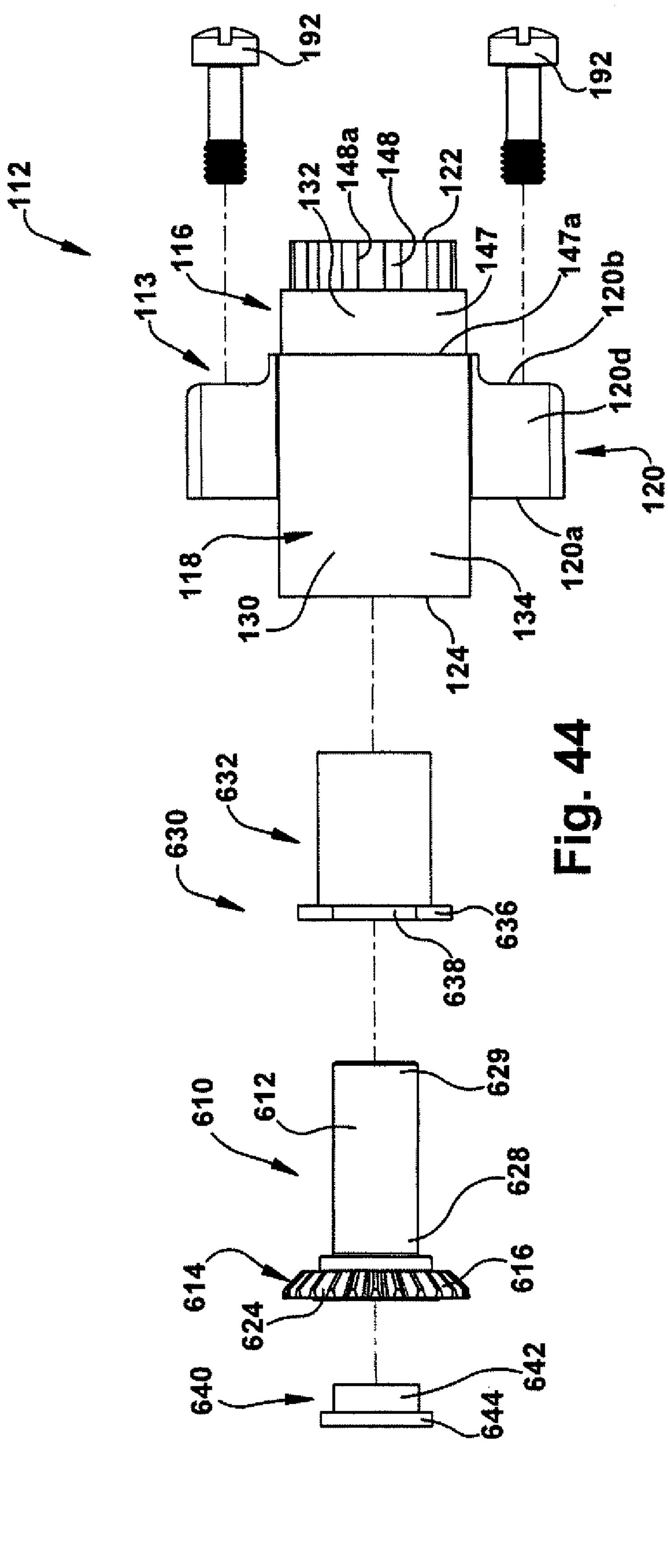
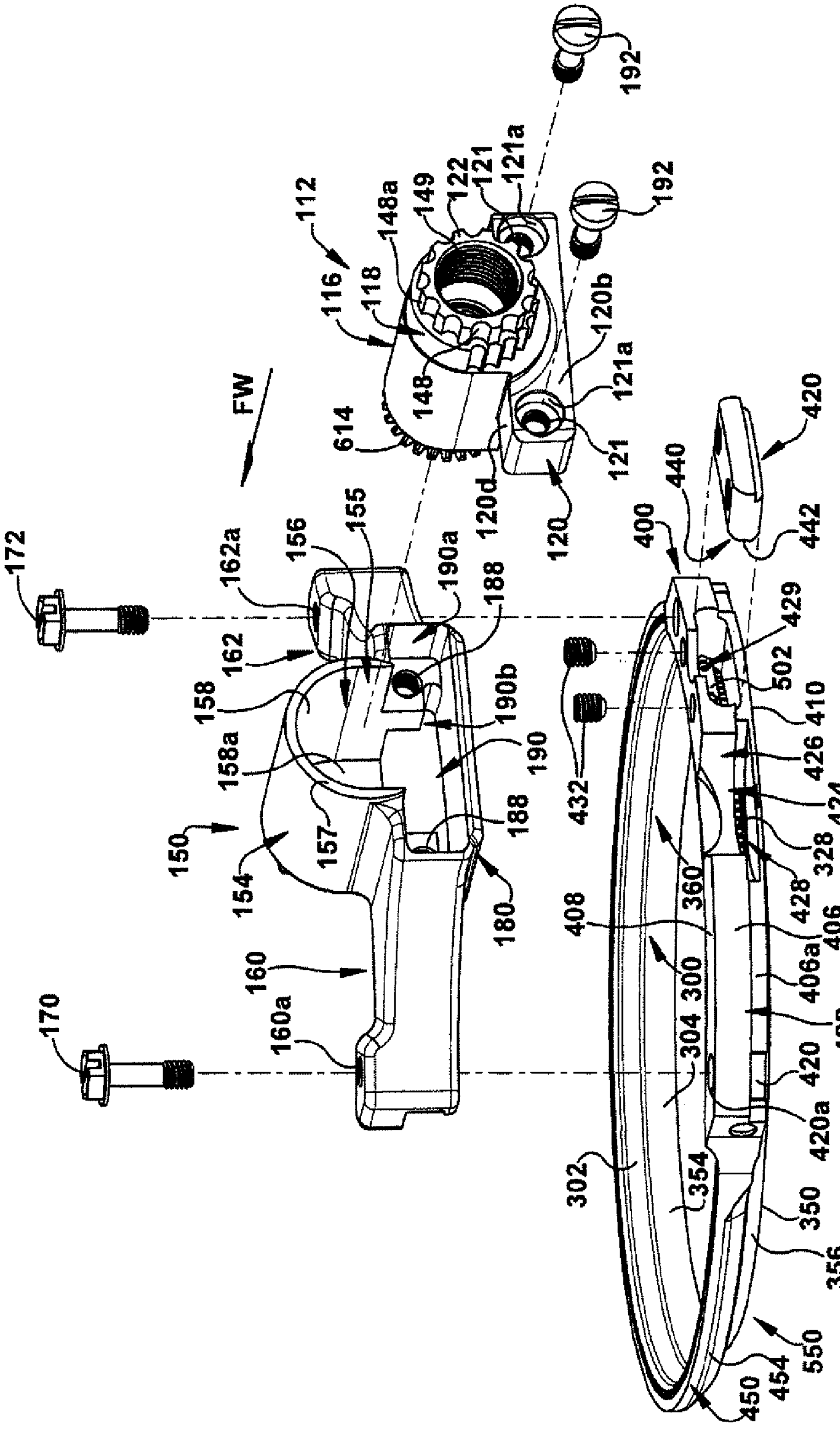

192
192
112
113
116
132
148a
148
122
147
147a
120b
120d
120
120a
118
130
134
124
632
630
636
638
610
612
629
628
614
616
624
640
642
644

Fig. 44



192
192
112
116
118
148a
149
122
121
121a
120b
120a
121a
121
120
120d
148
614
FW
172
162a
156
155
190a
188
162
158
190b
158a
190
432
150
154
157
188
180
160
160a
170
400
440
420
442
429
502
410
426
424
328
428
360
408
406
406a
300
402
304
420
420a
302
354
350
356
550
454
450

Fig. 45

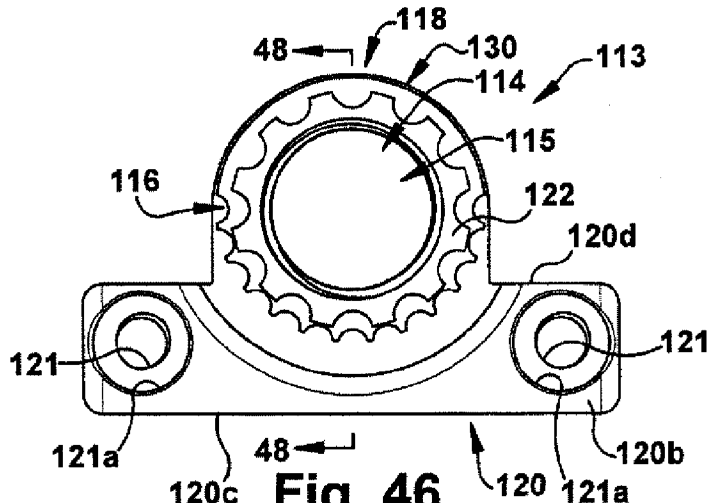


Fig. 46

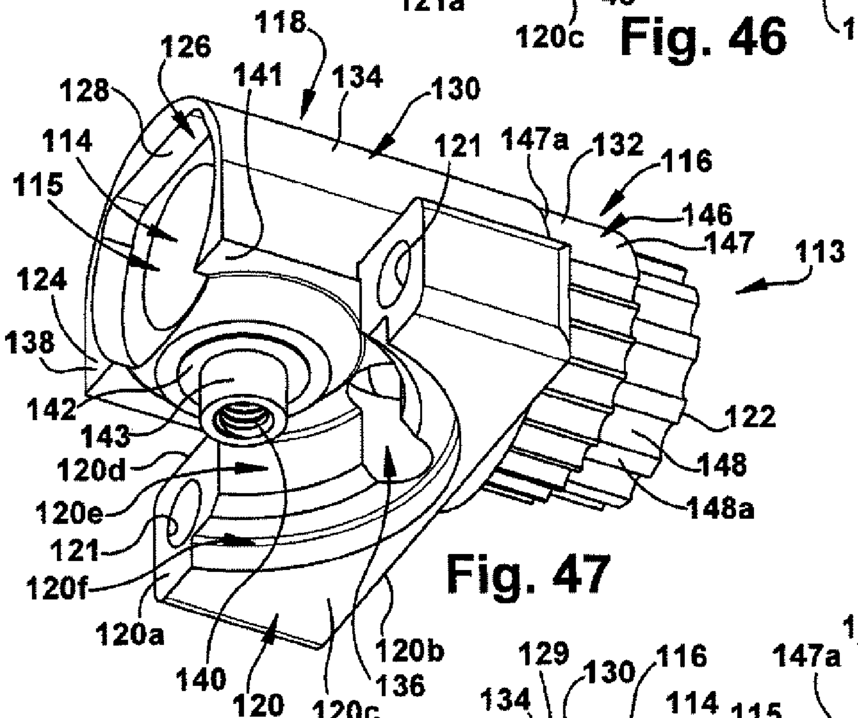


Fig. 47

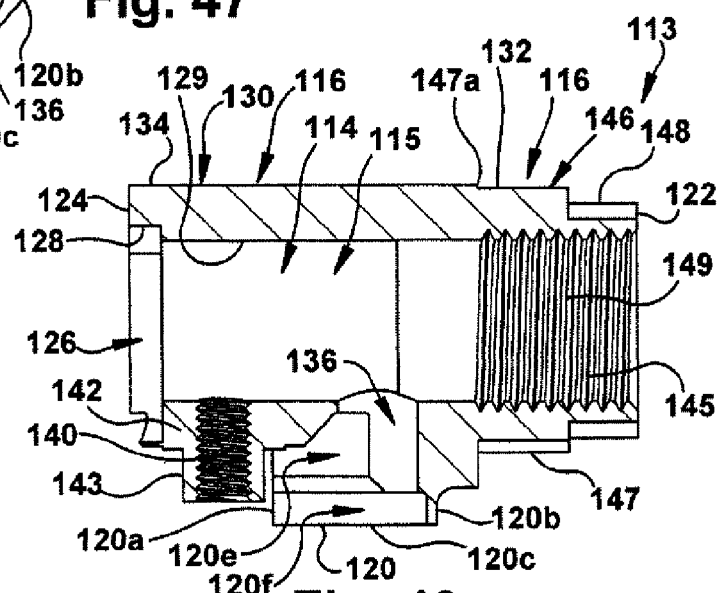


Fig. 48

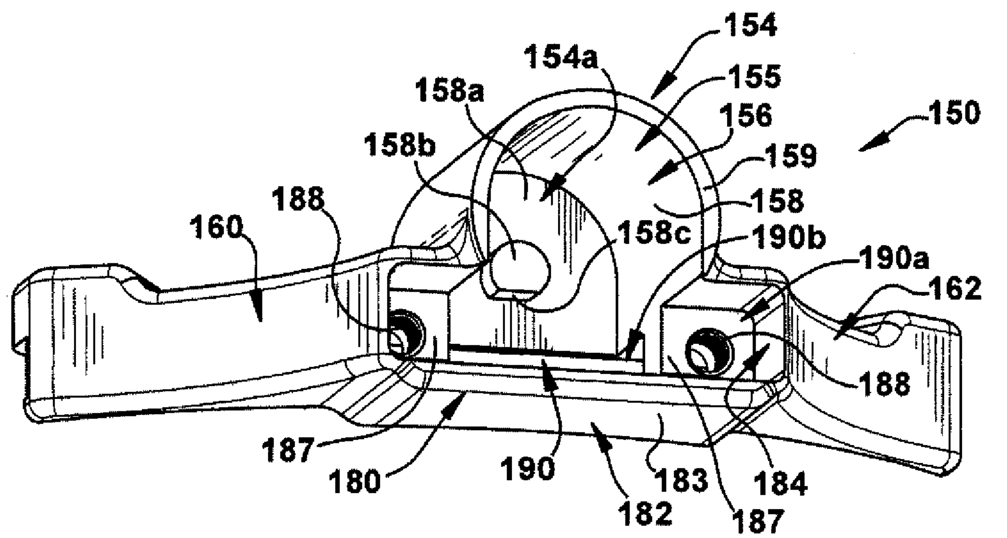

154
154a
155
158a
156
150
158b
159
188
158
160
158c
190b
190a
162
188
187
190
183
184
180
182
187

Fig. 49

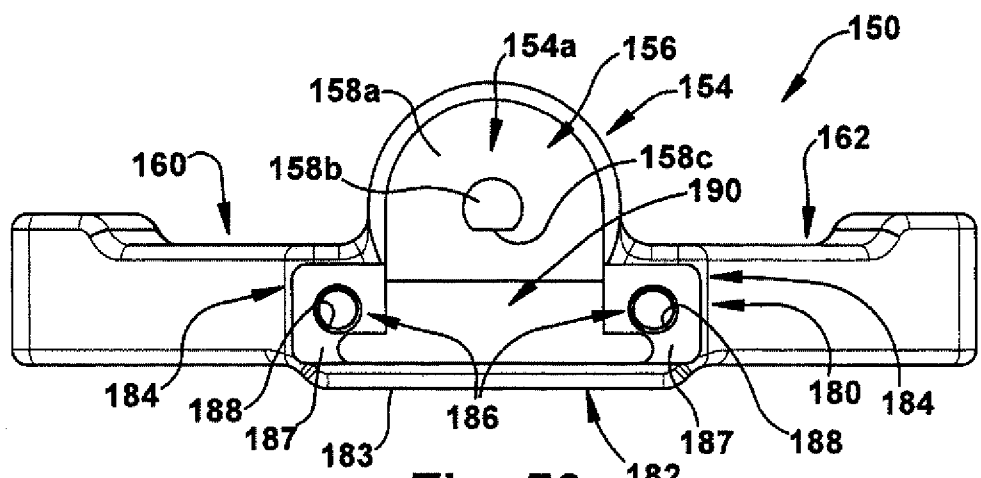
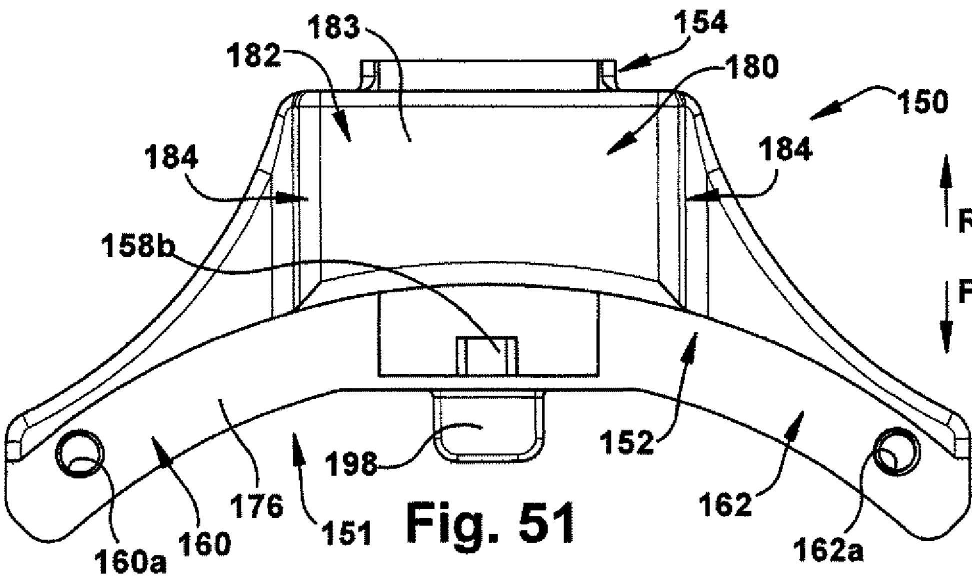
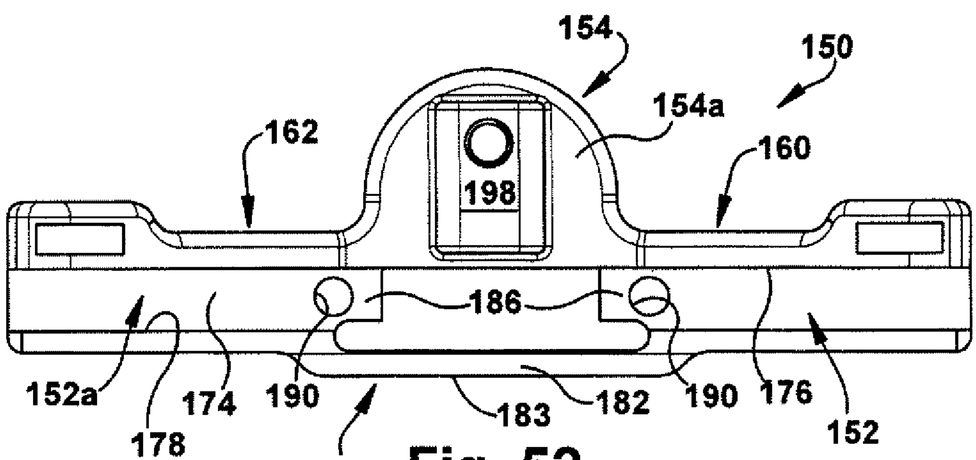

154a
156
150
158a
154
162
160
158c
158b
190
184
188
186
180
184
187
183
182
187
188

Fig. 50



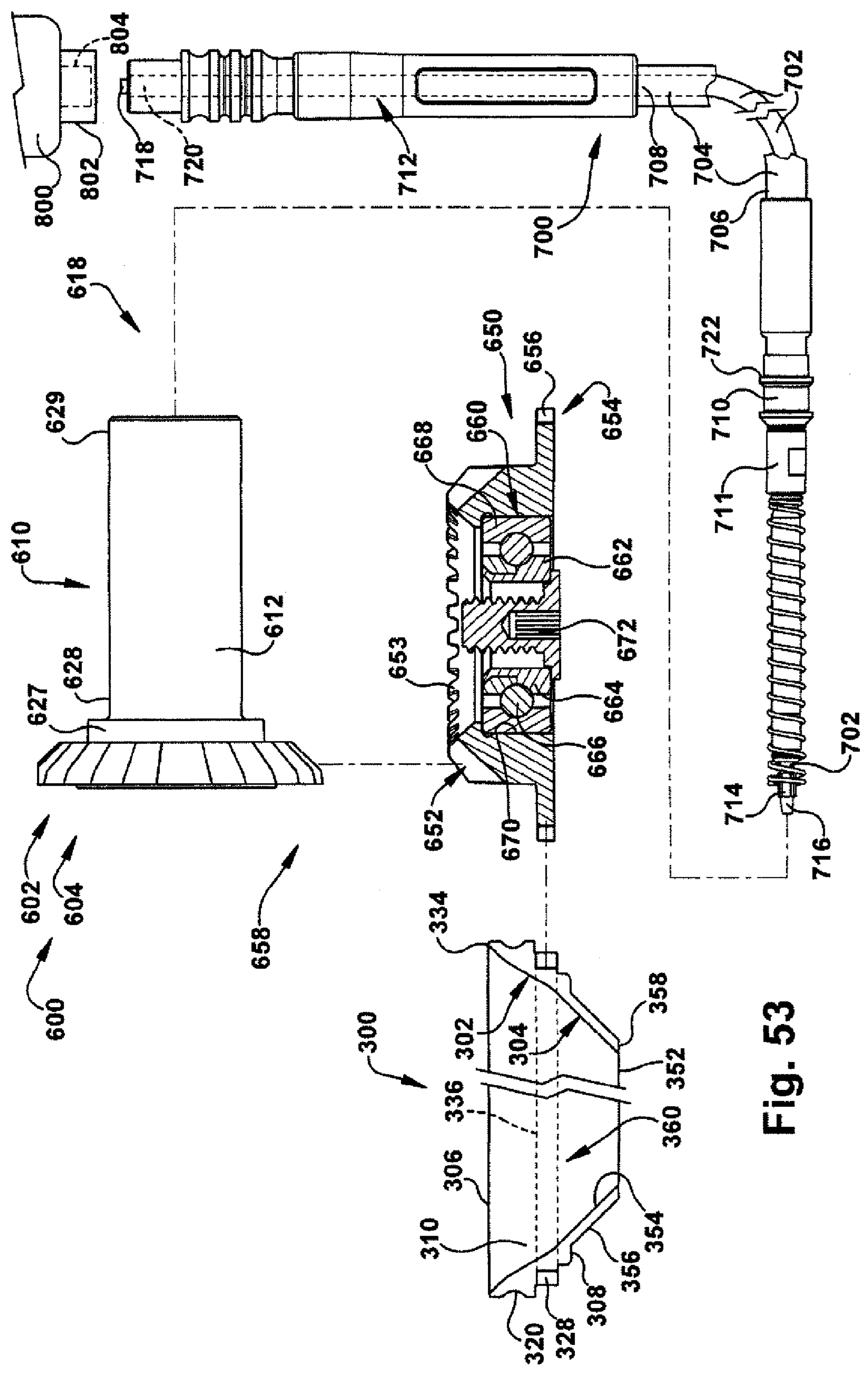
183
154
182
180
150
184
184
RW
158b
FW
152
198
176
162
160a
160
151
162a

Fig. 51



154
150
154a
162
160
198
186
152a
178
174
190
183
182
190
176
152
180

Fig. 52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662
672
653
664
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352
300
336
360
306
310
354
356
308
320
328

Fig. 53

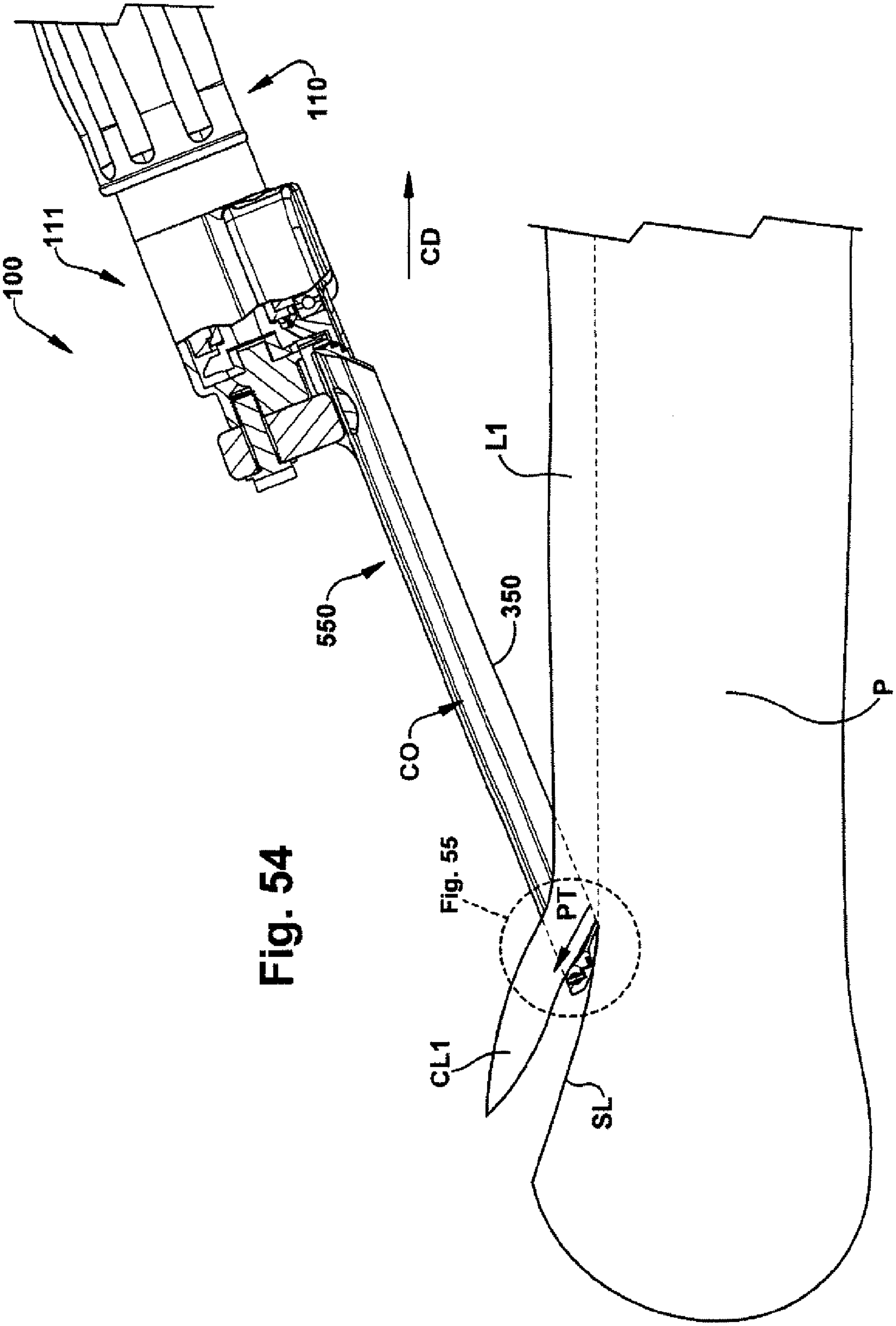


Fig. 54

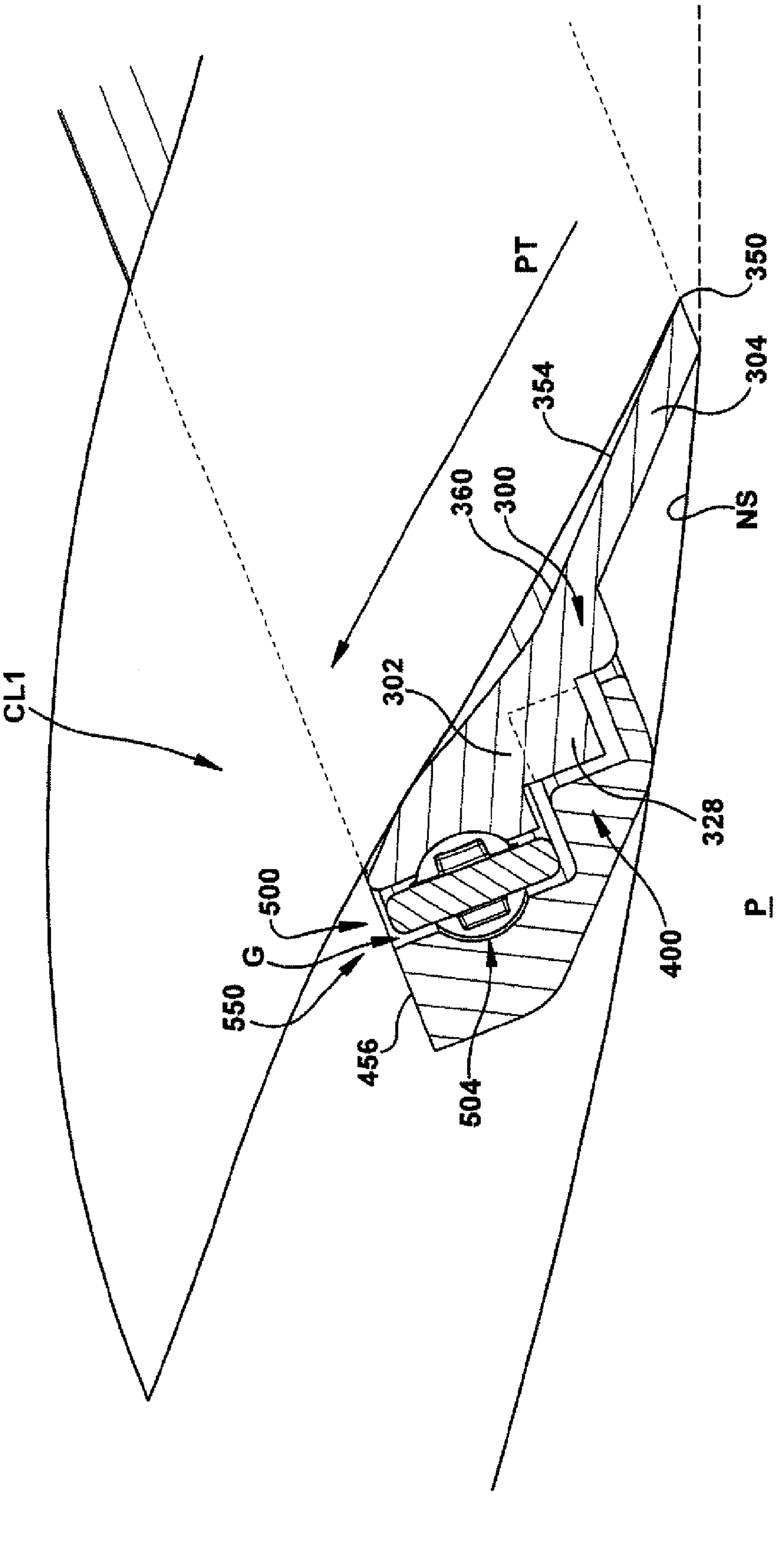
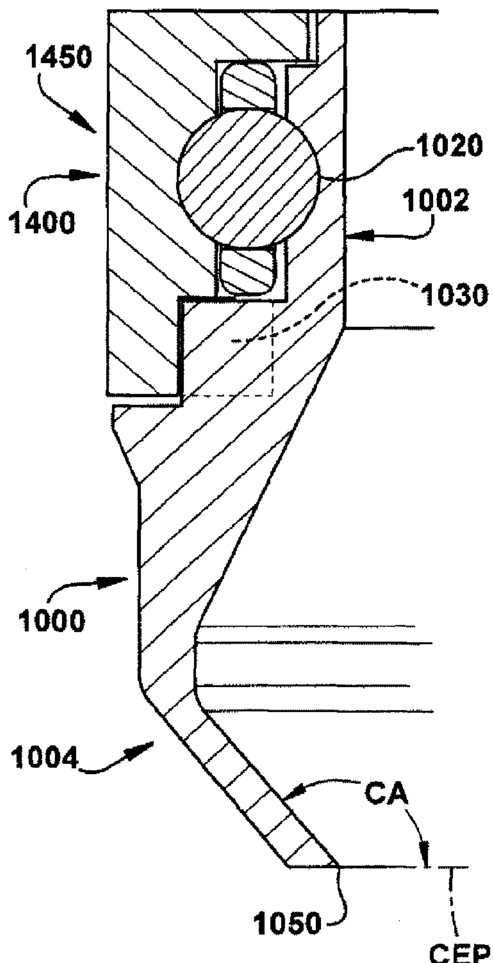
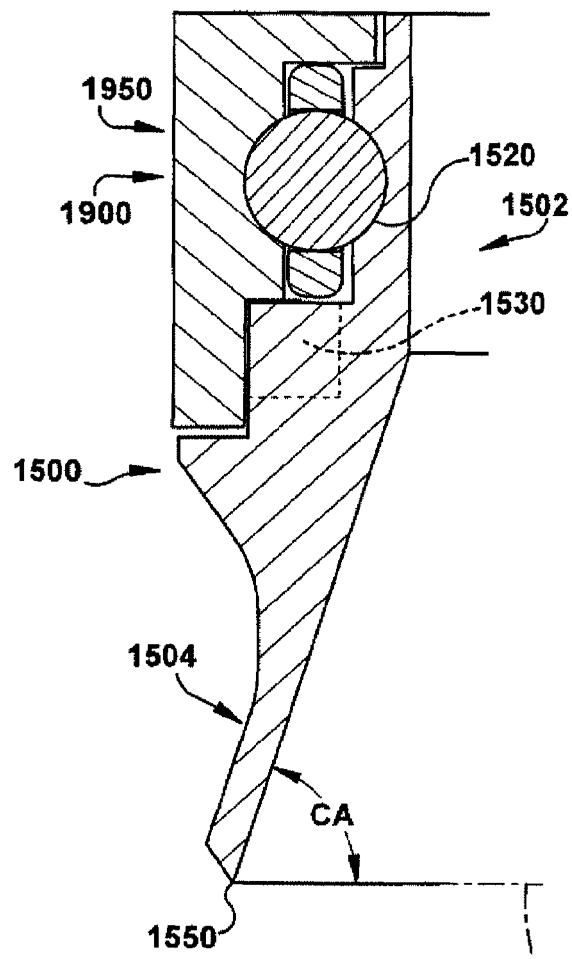


Fig. 55



1450
1400
1020
1002
1030
1000
1004
CA
1050
CEP

Fig. 56



1950
1900
1520
1502
1530
1500
1504
CA
1550
CEP

Fig. 57

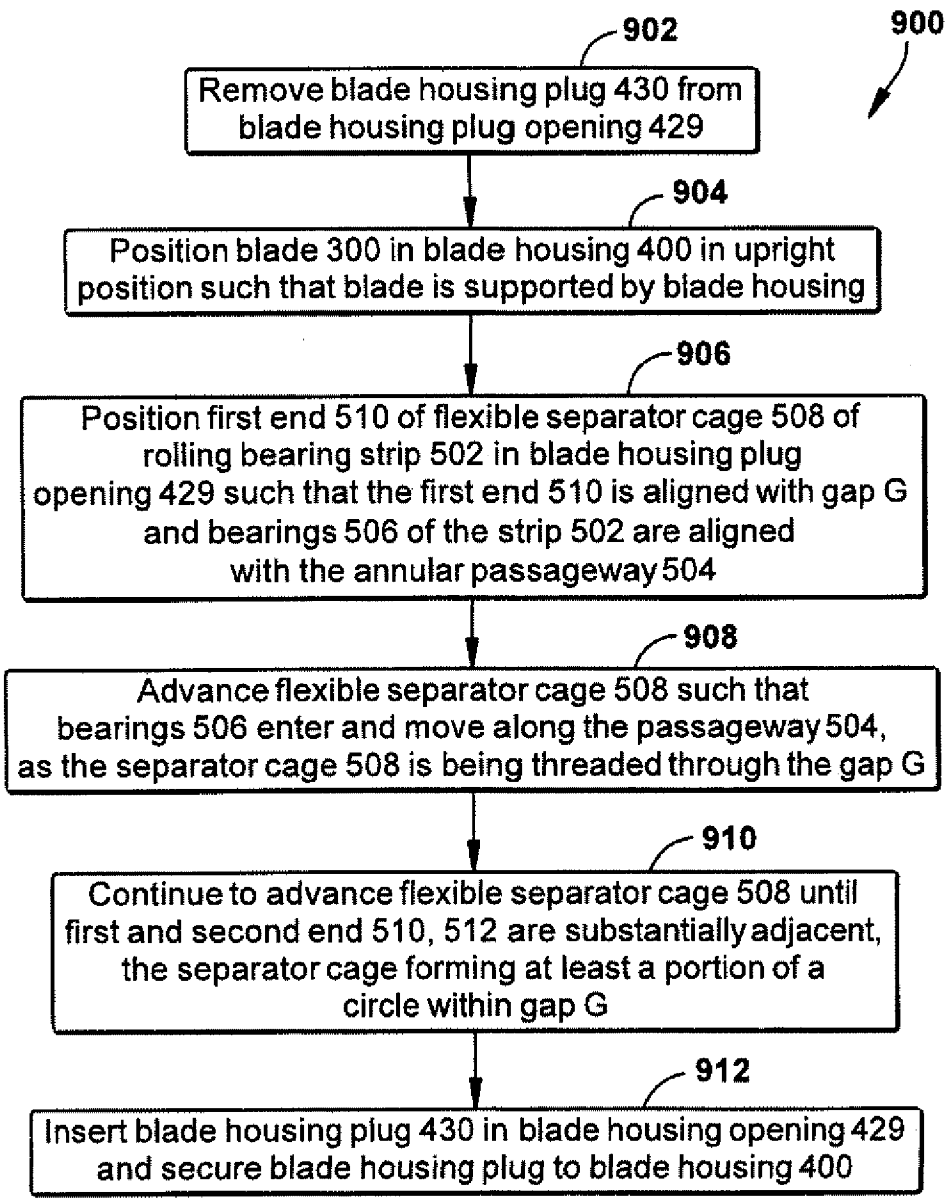

900
902
Remove blade housing plug 430 from blade housing plug opening 429
904
Position blade 300 in blade housing 400 in upright position such that blade is supported by blade housing
906
Position first end 510 of flexible separator cage 508 of rolling bearing strip 502 in blade housing plug opening 429 such that the first end 510 is aligned with gap G and bearings 506 of the strip 502 are aligned with the annular passageway 504
908
Advance flexible separator cage 508 such that bearings 506 enter and move along the passageway 504, as the separator cage 508 is being threaded through the gap G
910
Continue to advance flexible separator cage 508 until first and second end 510, 512 are substantially adjacent, the separator cage forming at least a portion of a circle within gap G
912
Insert blade housing plug 430 in blade housing opening 429 and secure blade housing plug to blade housing 400

Fig. 58

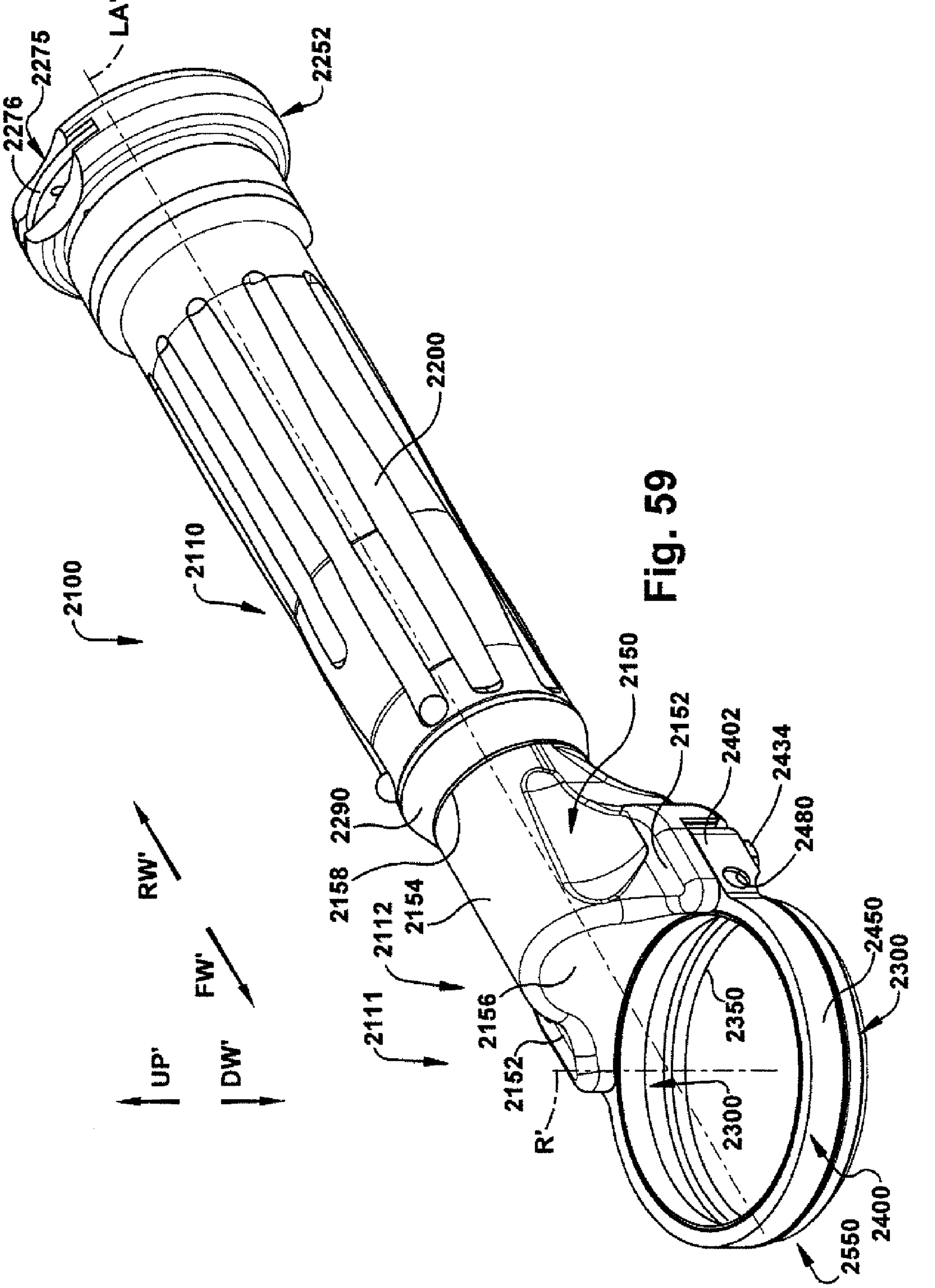

LA'
2275
2276
2252
2200
2110
2100
2150
2152
2402
2434
2480
2290
2158
2112
2154
2156
2111
2152
R'
RW'
FW'
UP'
DW'
2350
2300
2450
2300
2300
2400
2550

Fig. 59

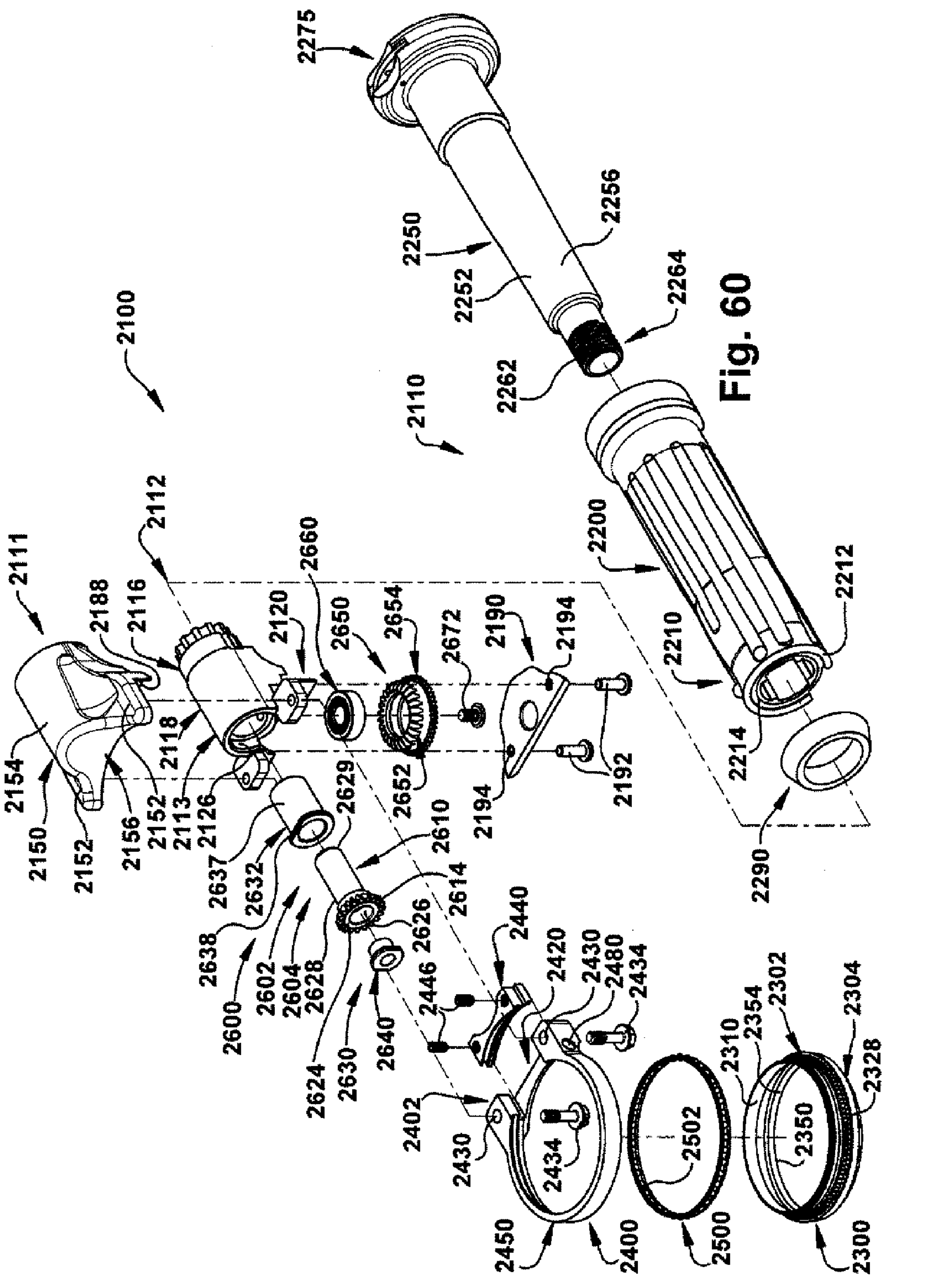

2275
2250
2256
2252
2264
2262
2100
2110
2112
2111
2188
2116
2660
2120
2650
2654
2672
2190
2194
2200
2212
2210
2214
2192
2194
2290
2154
2118
2150
2152
2156
2152
2113
2126
2629
2652
2610
2637
2632
2614
2638
2626
2602
2604
2628
2600
2440
2420
2430
2480
2434
2446
2624
2630
2640
2402
2430
2434
2450
2400
2502
2500
2310
2354
2302
2304
2328
2350
2300

Fig. 60

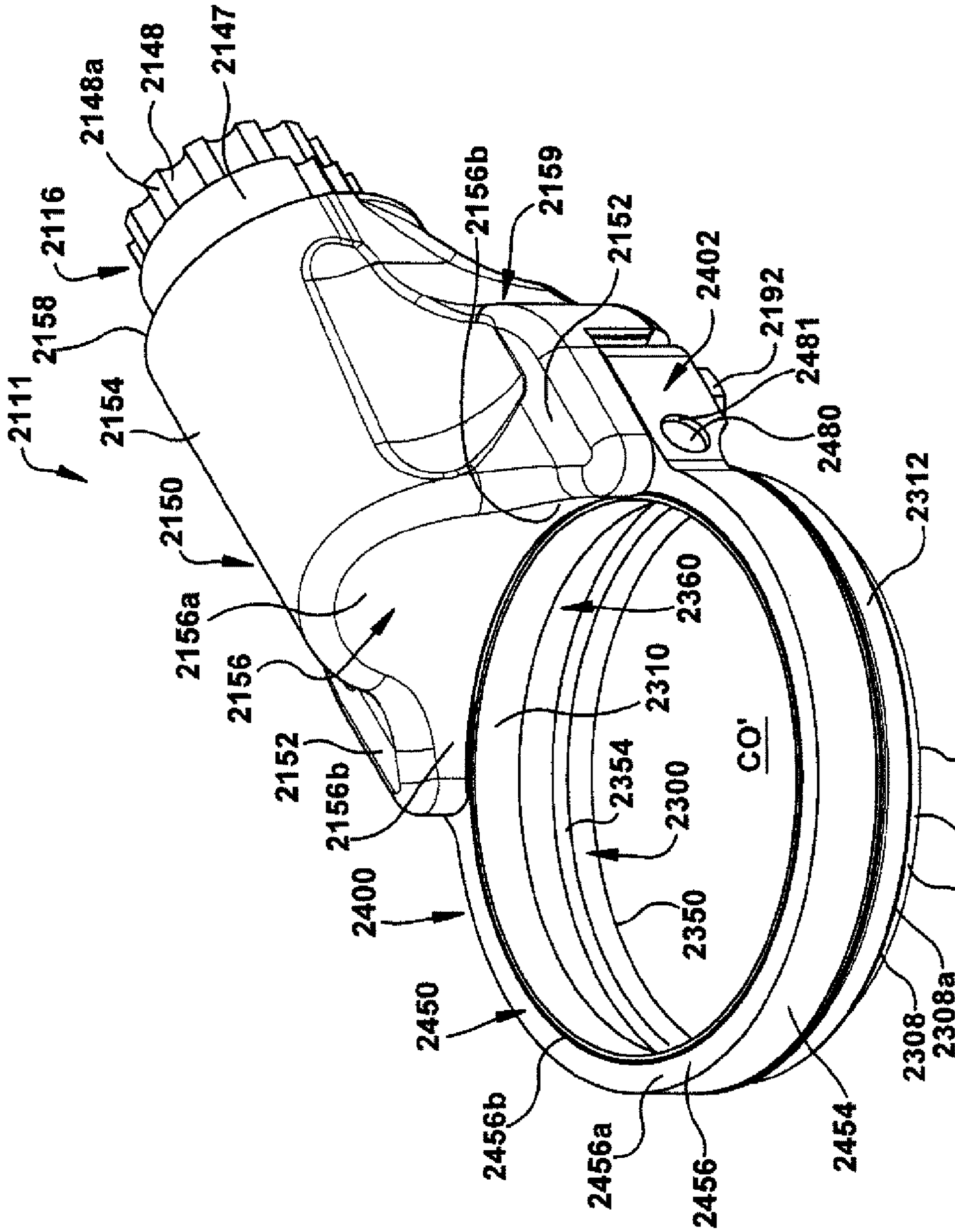
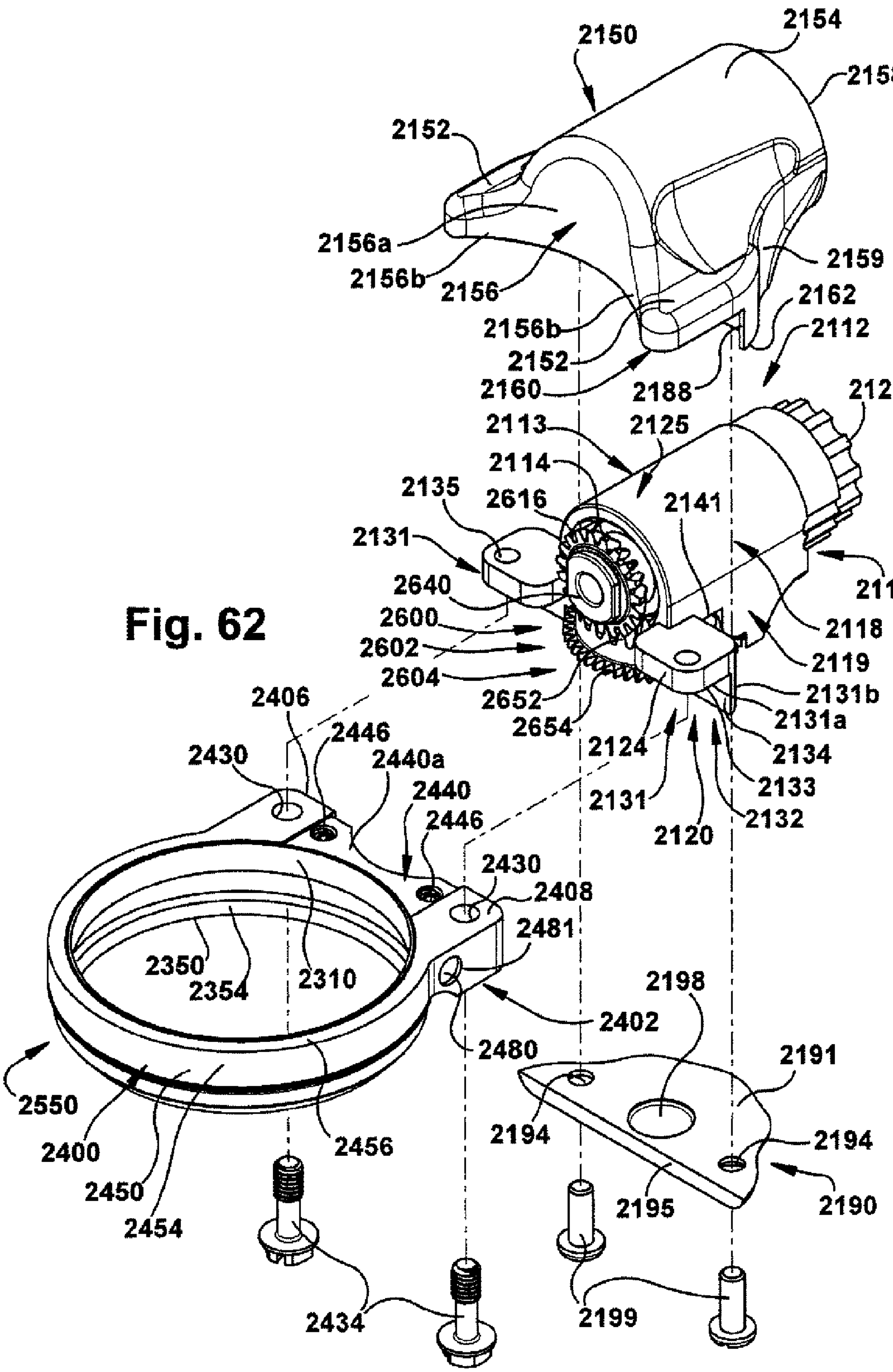

2111
2116
2147
2148
2148a
2150
2152
2154
2156
2156a
2156b
2158
2159
2192
2300
2308
2308a
2310
2312
2350
2352
2354
2356
2360
2400
2402
2450
2454
2456
2456a
2456b
2480
2481
CO'

Fig. 61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2154
2158
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2156a
2156b
2156
2159
2162
2156b
2152
2112
2160
2188
2122
2113
2125
2114
2141
2135
2616
2131
2116
2640
2118
2600
2602
2119
2604
2131b
2652
2131a
2654
2134
2124
2133
2131
2132
2120
2406
2446
2430
2440a
2440
2446
2430
2408
2481
2350
2354
2310
2198
2402
2480
2191
2550
2194
2194
2400
2456
2450
2195
2190
2454
2434
2199

Fig. 62

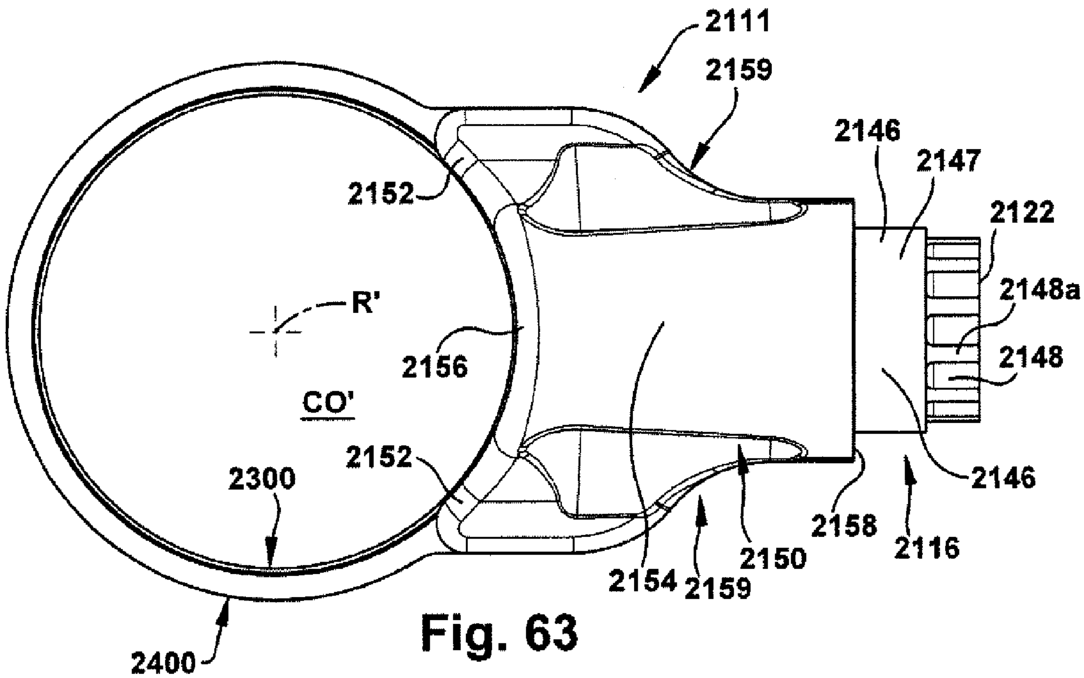
2111
2159
2146
2147
2122
2152
2148a
R'
2148
2156
CO'
2152
2300
2146
2158
2116
2150
2154
2159
2400

Fig. 63

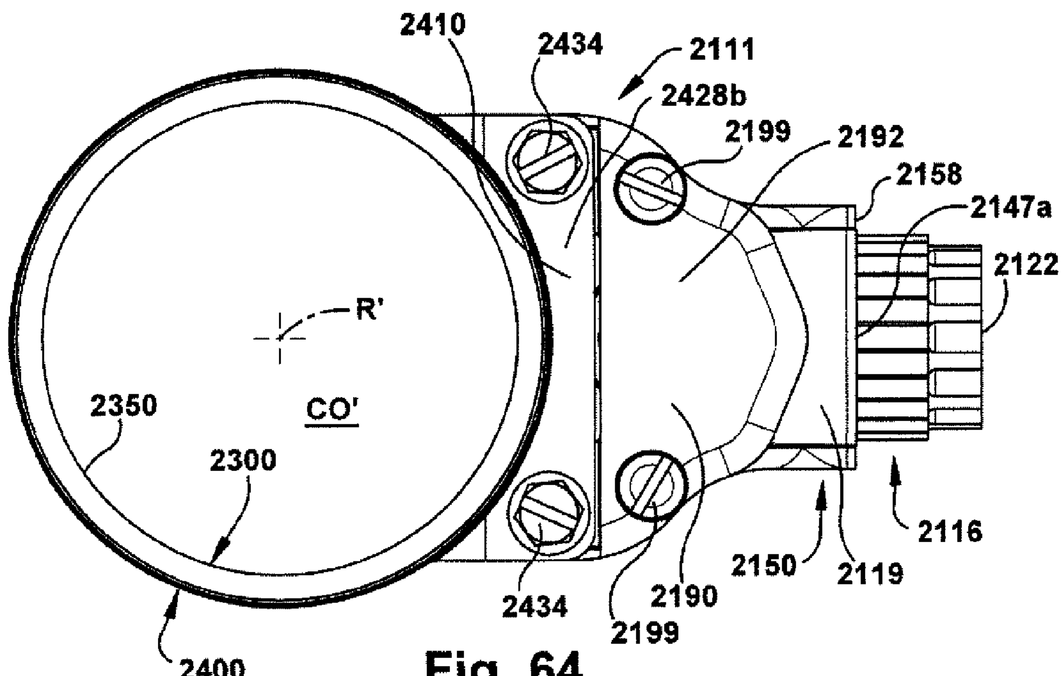
2410
2434
2111
2428b
2199
2192
2158
2147a
2122
R'
2350
CO'
2300
2116
2150
2119
2190
2434
2199
2400

Fig. 64

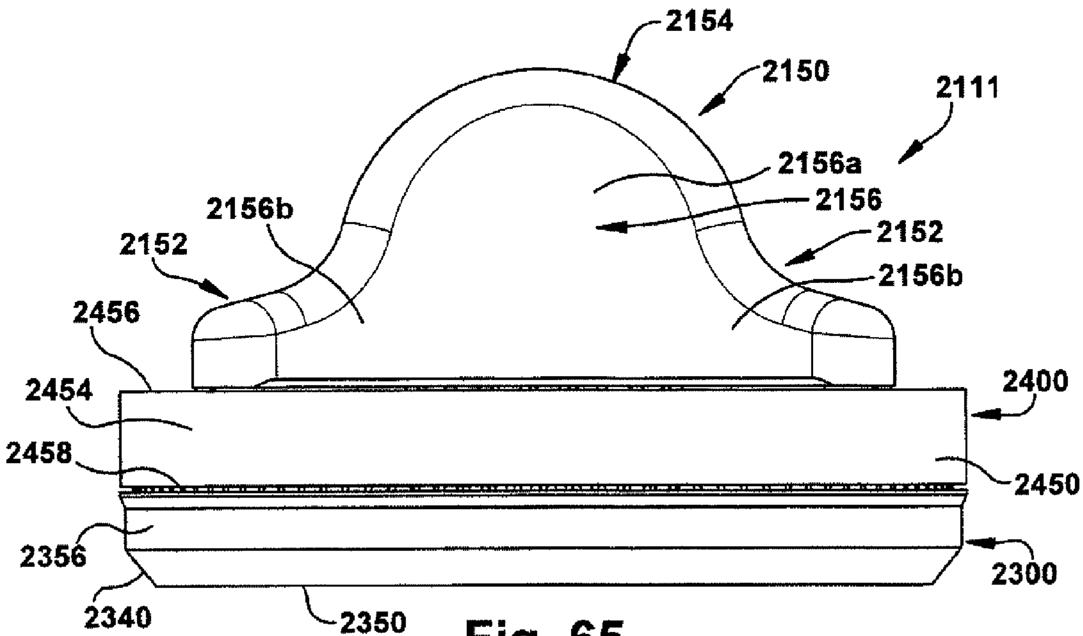
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Fig. 65

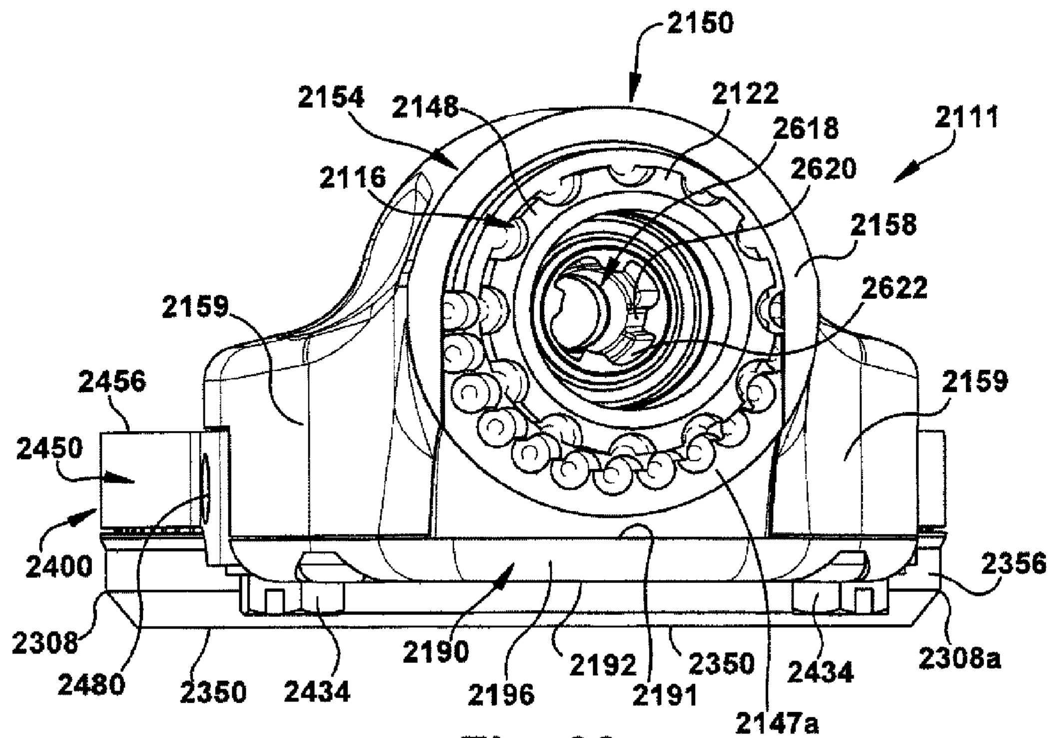
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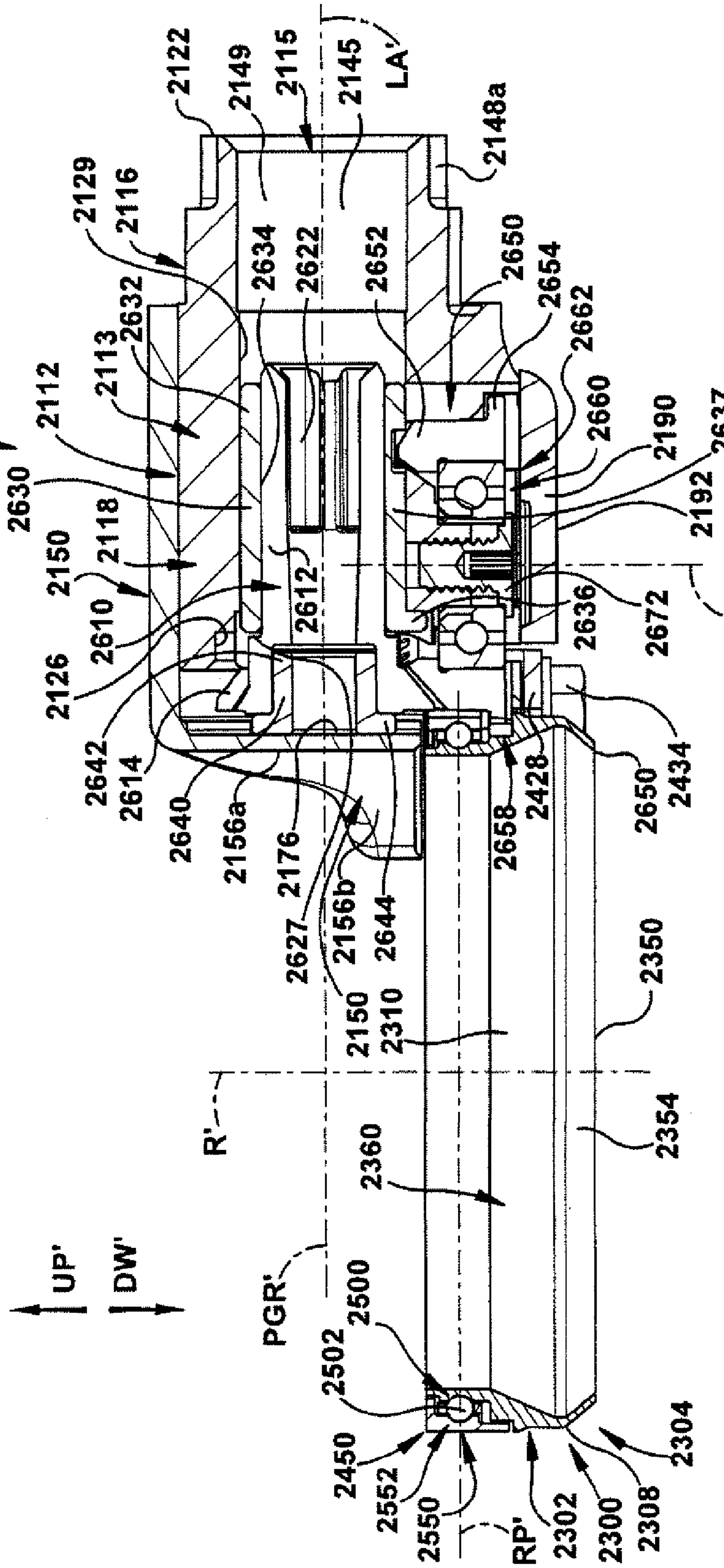
Fig. 66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2192
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DGR'
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2428
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2354
R'
RW'
FW'
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DW'
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RP'
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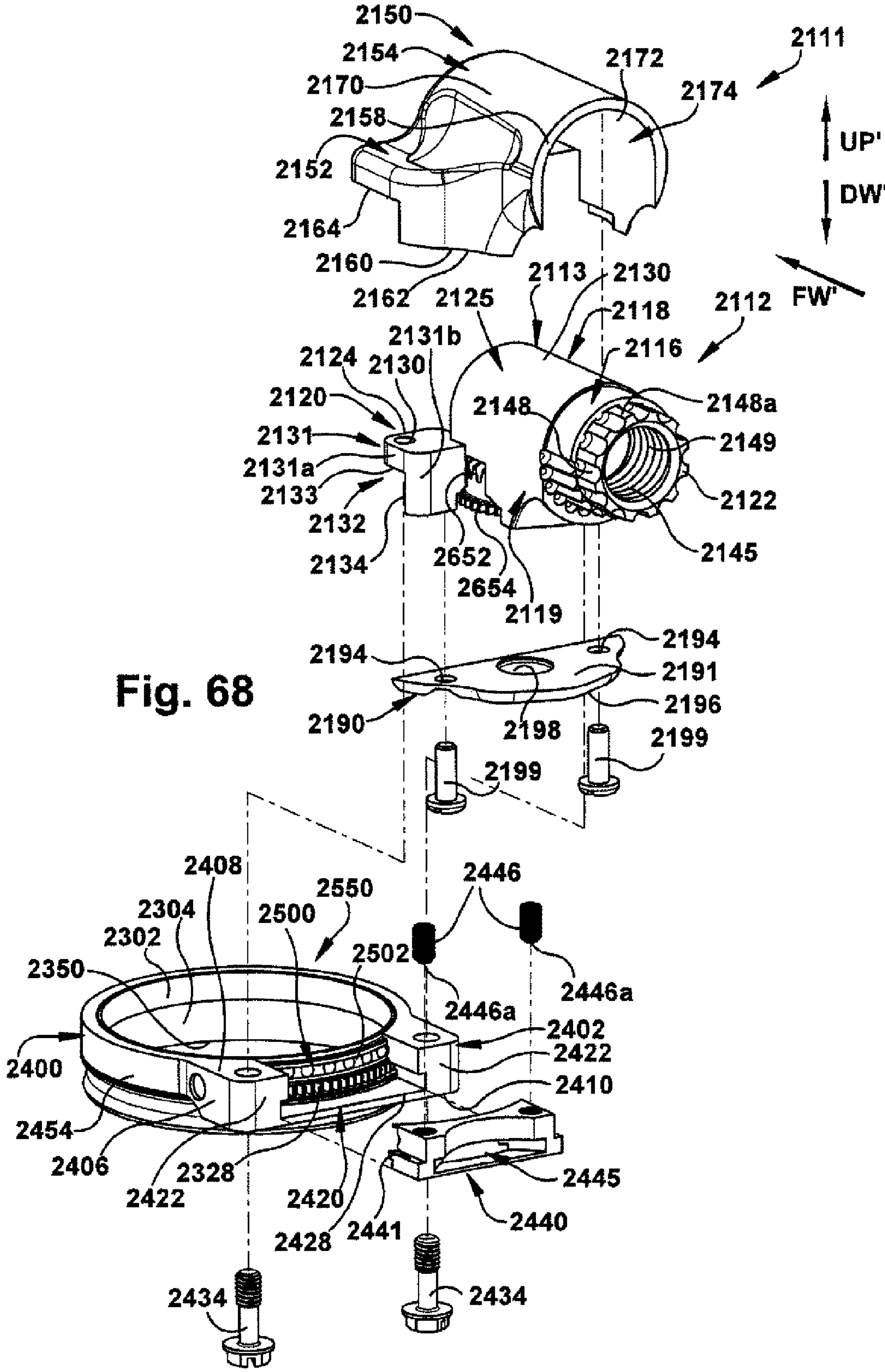
Fig. 67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2500
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2446a
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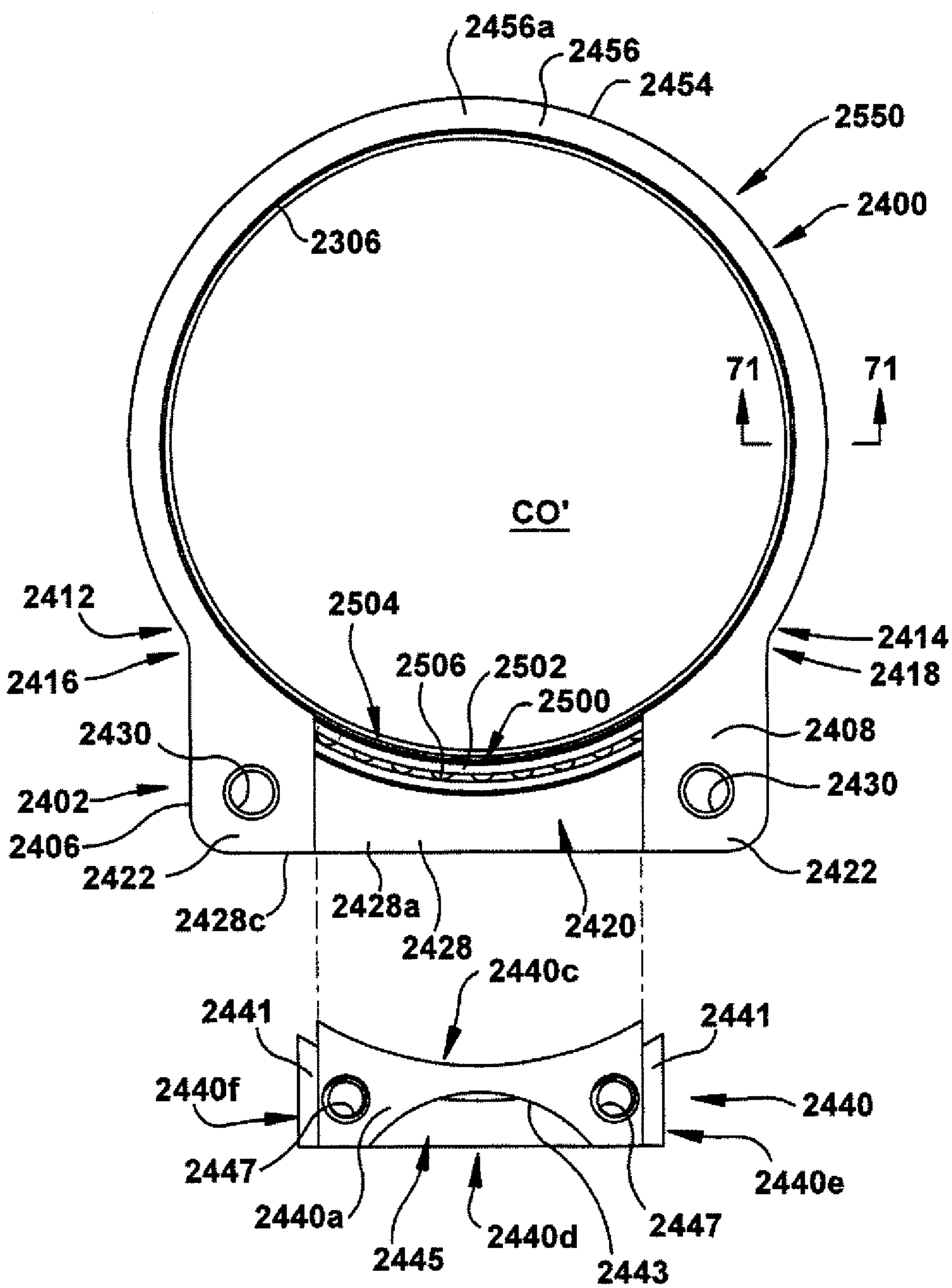
Fig. 68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2408
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2402
2406
2422
2422
2428c
2428a
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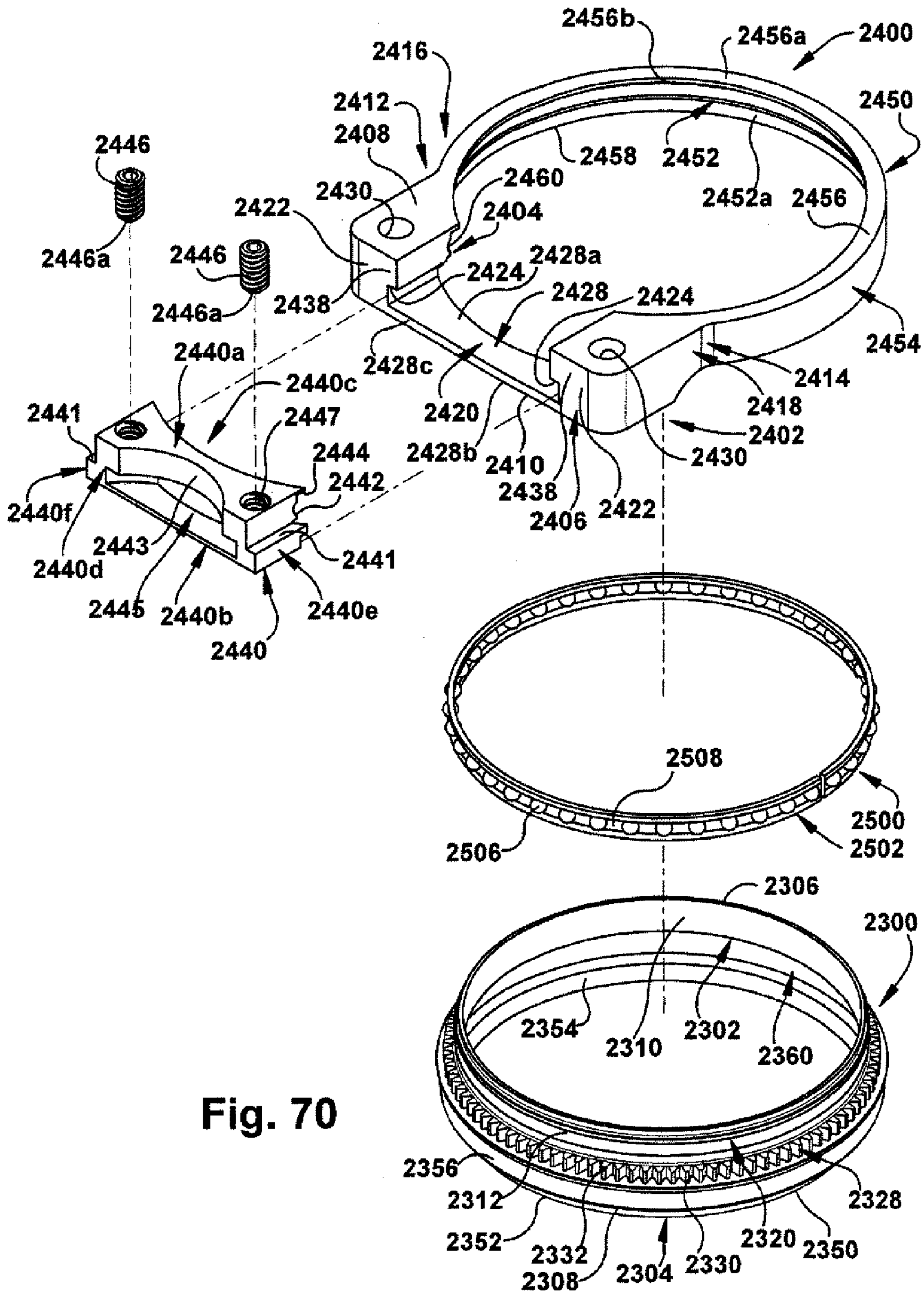
Fig. 69



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2454
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2428c
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2440c
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2440f
2442
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2406
2440d
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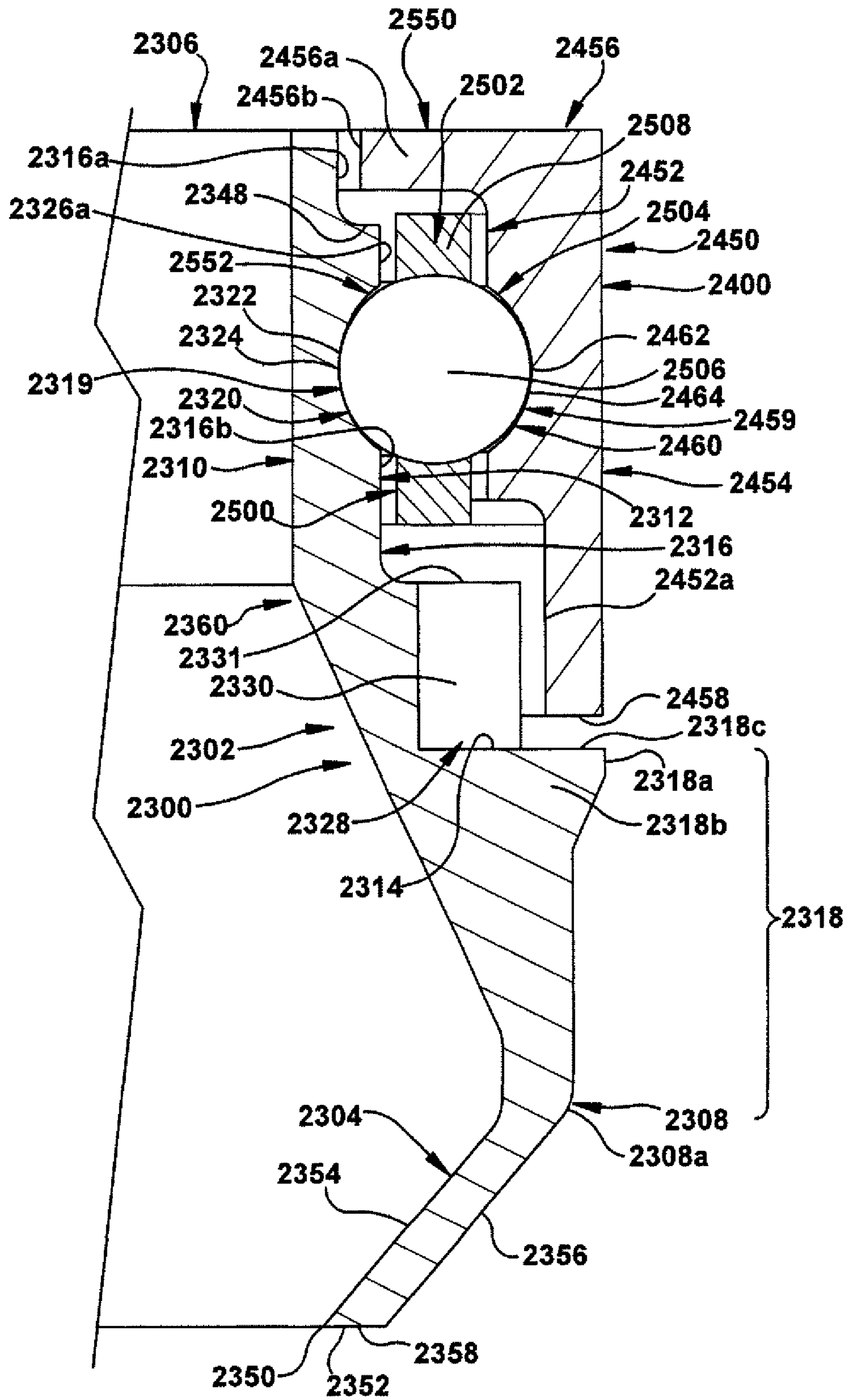
Fig. 70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2454
2500
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2316
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2318c
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2318a
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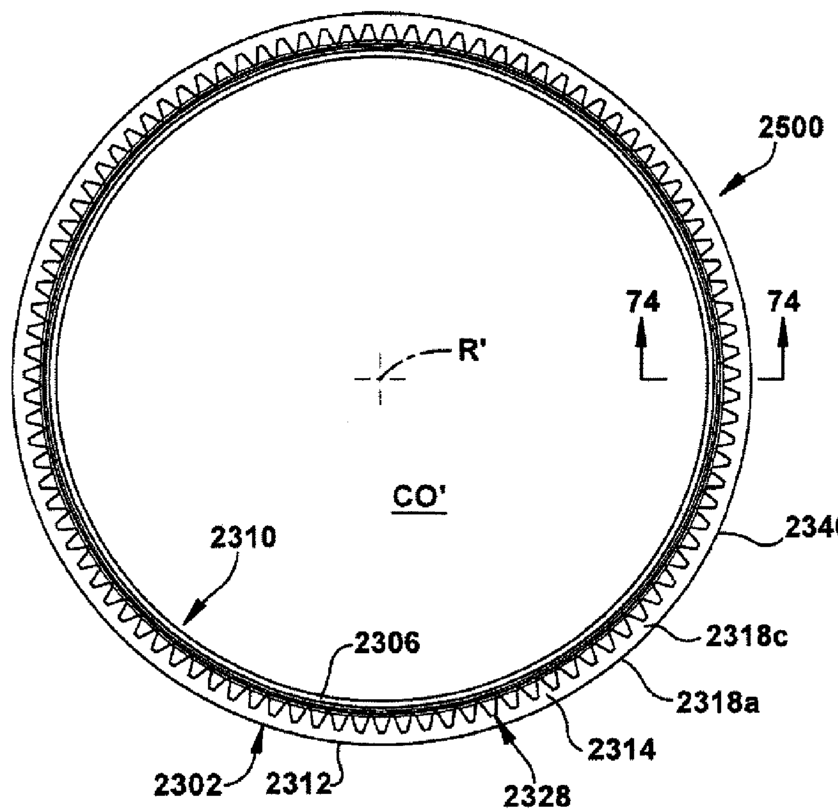
Fig. 71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CO'
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Fig. 72

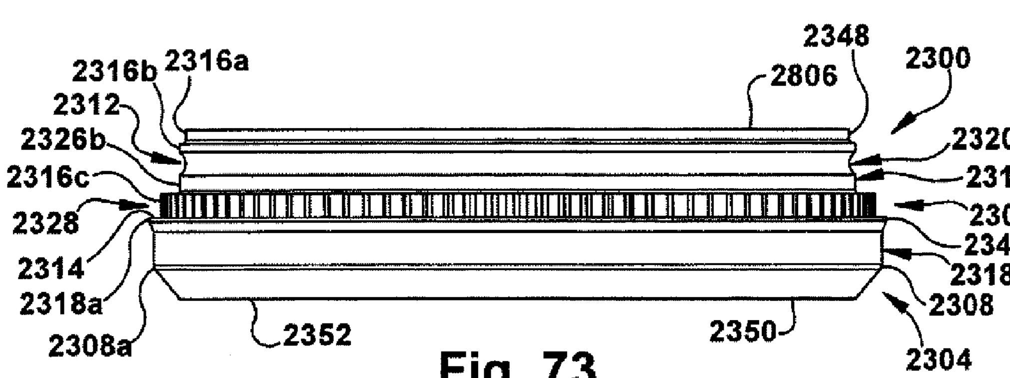
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Fig. 73

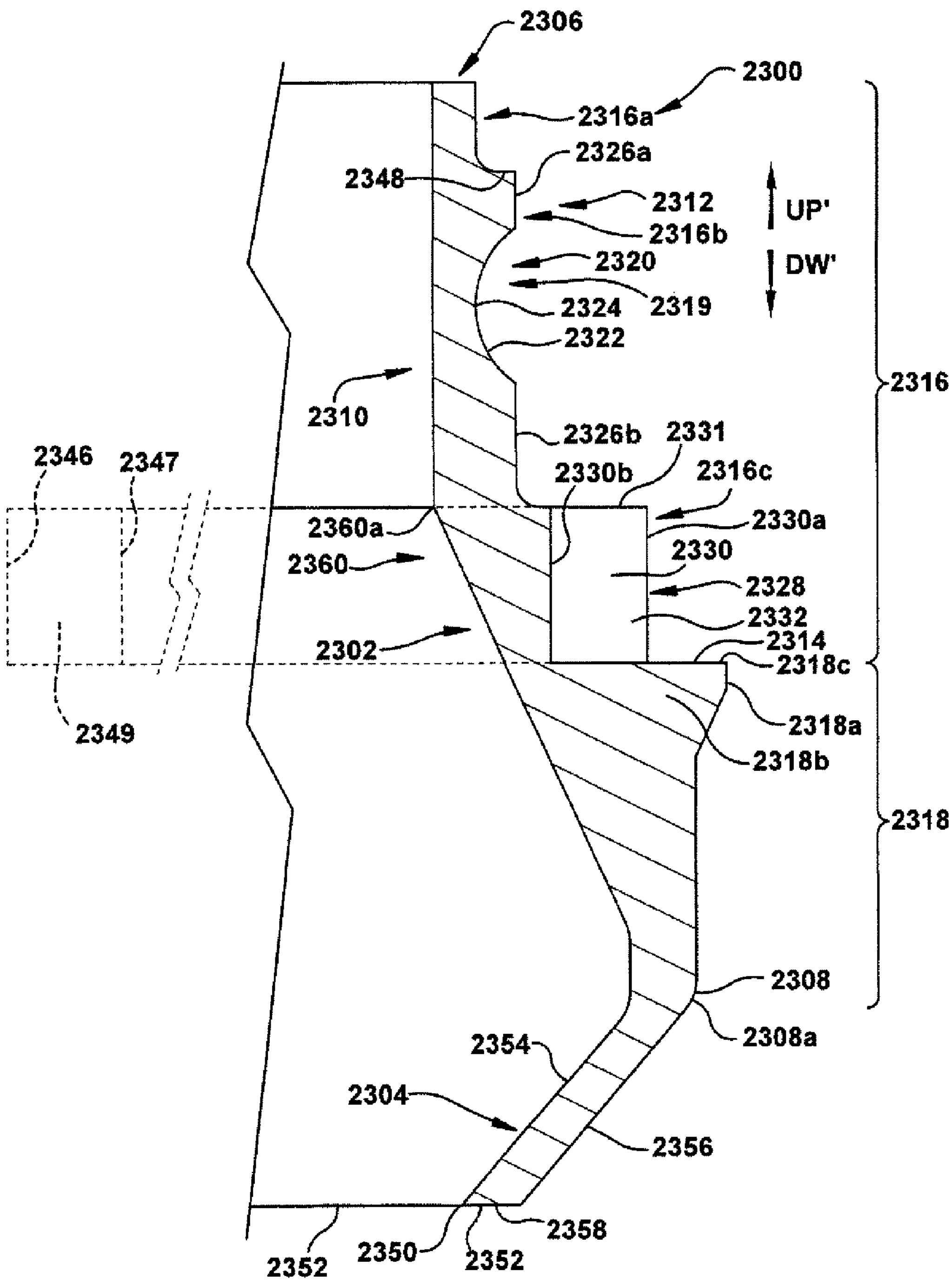
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Fig. 74

Fig. 75

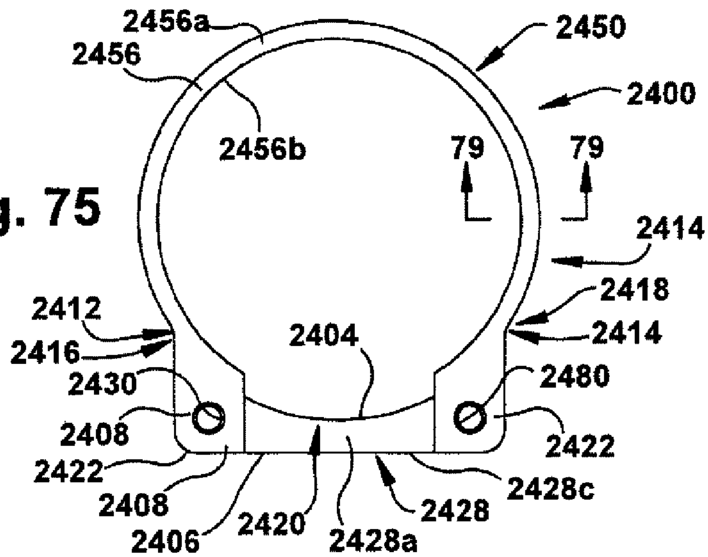


Fig. 76

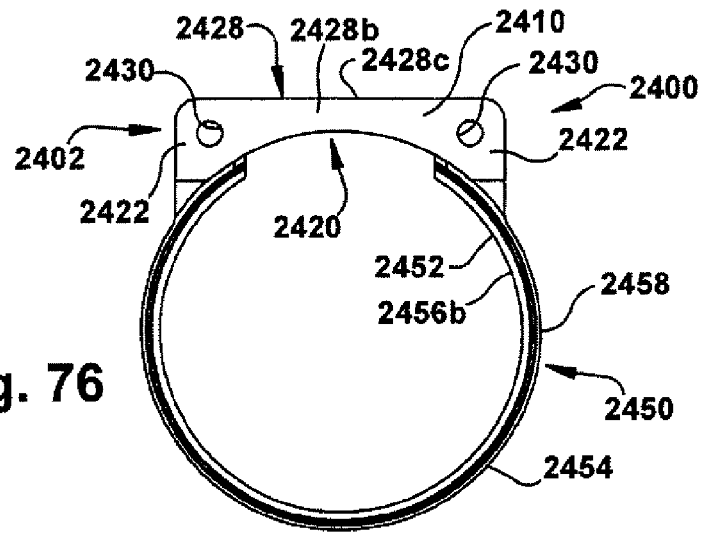


Fig. 77

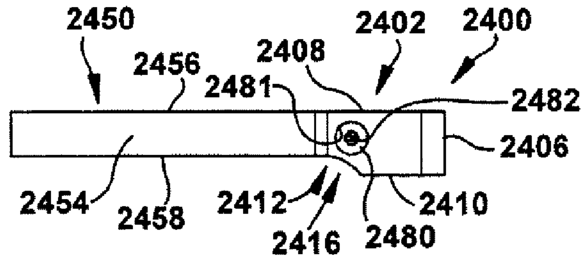
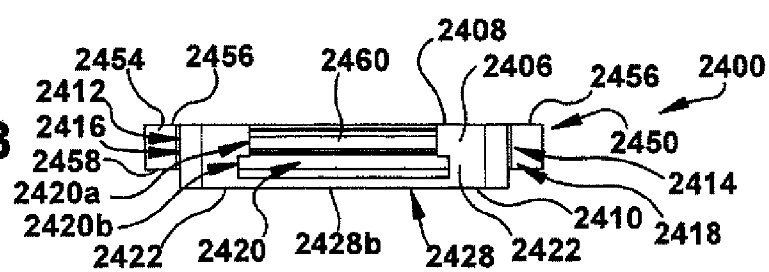


Fig. 78



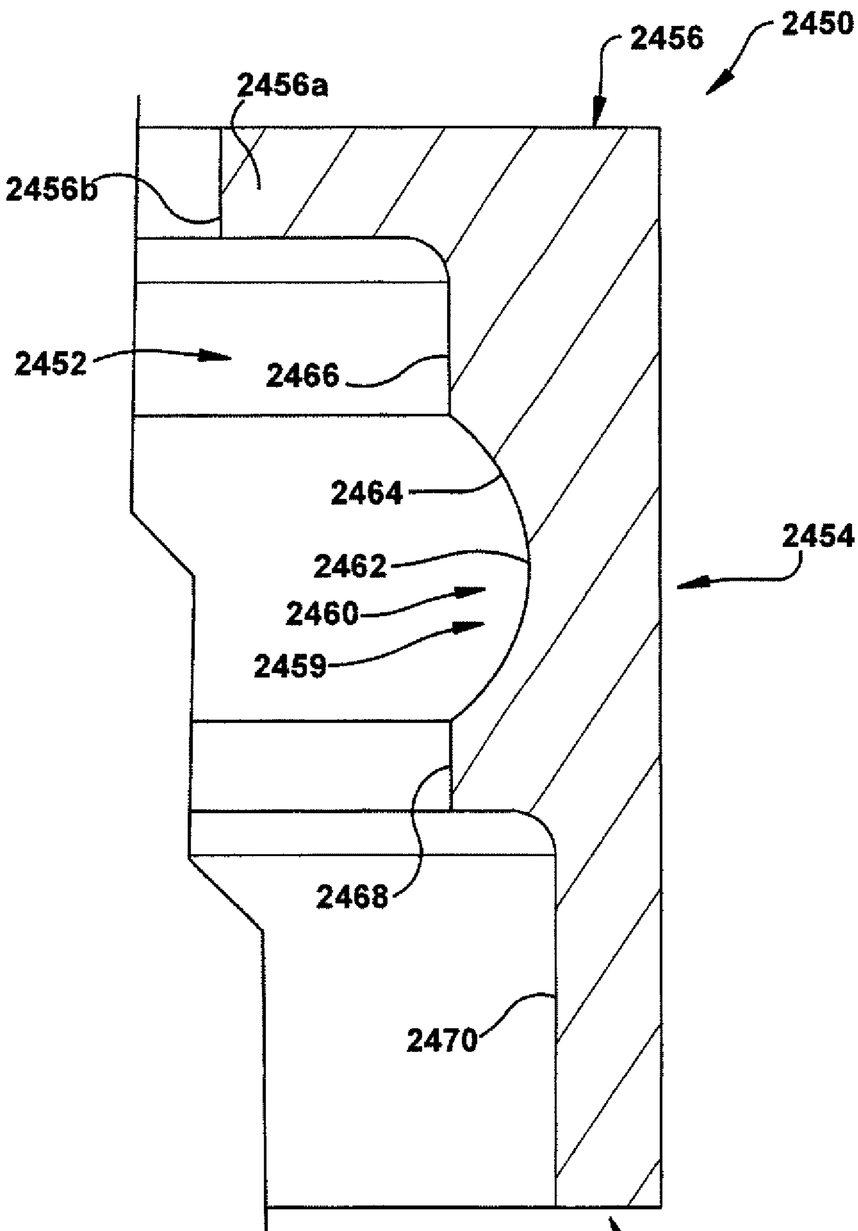

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Fig. 79

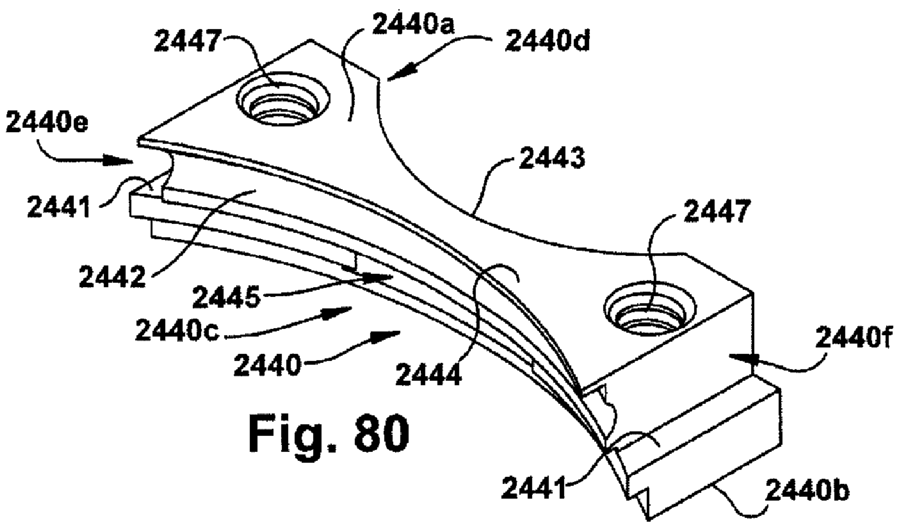

Fig. 80

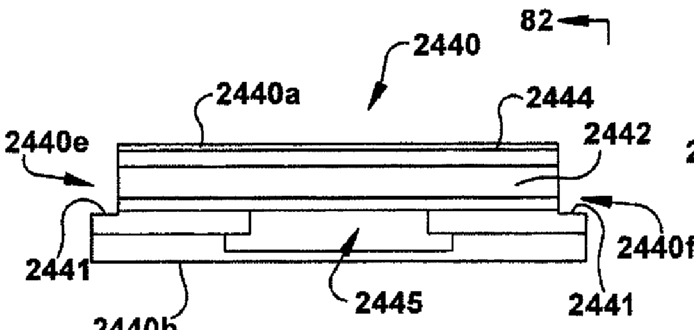

Fig. 81

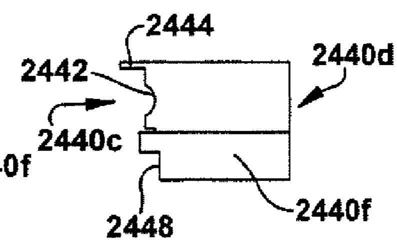

Fig. 82

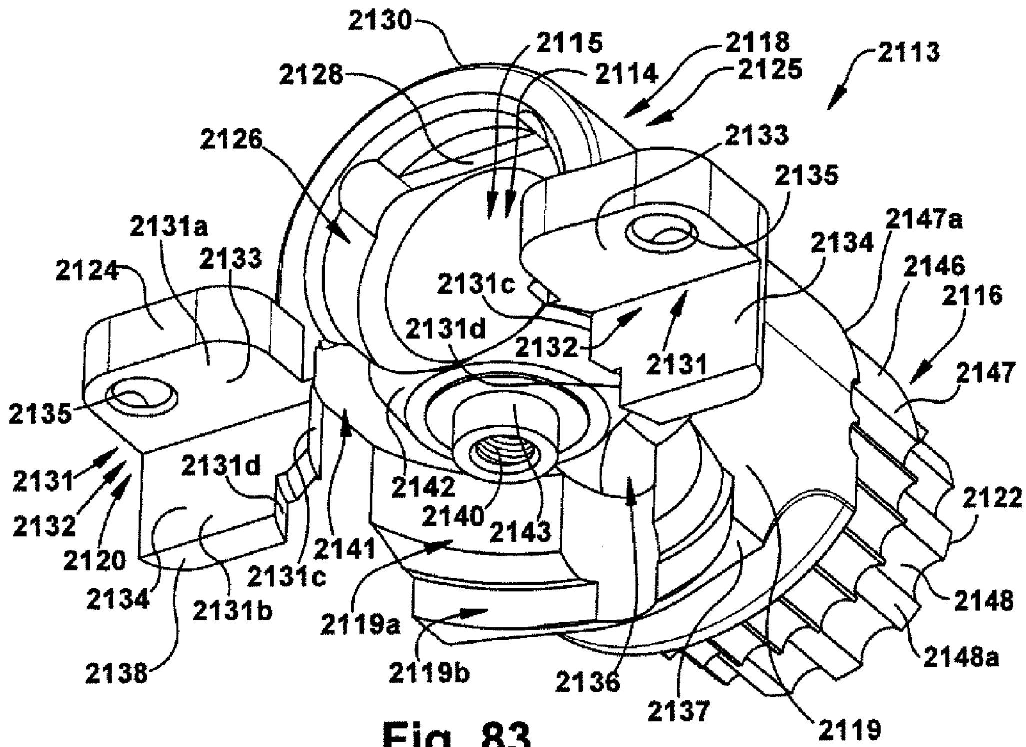
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Fig. 83

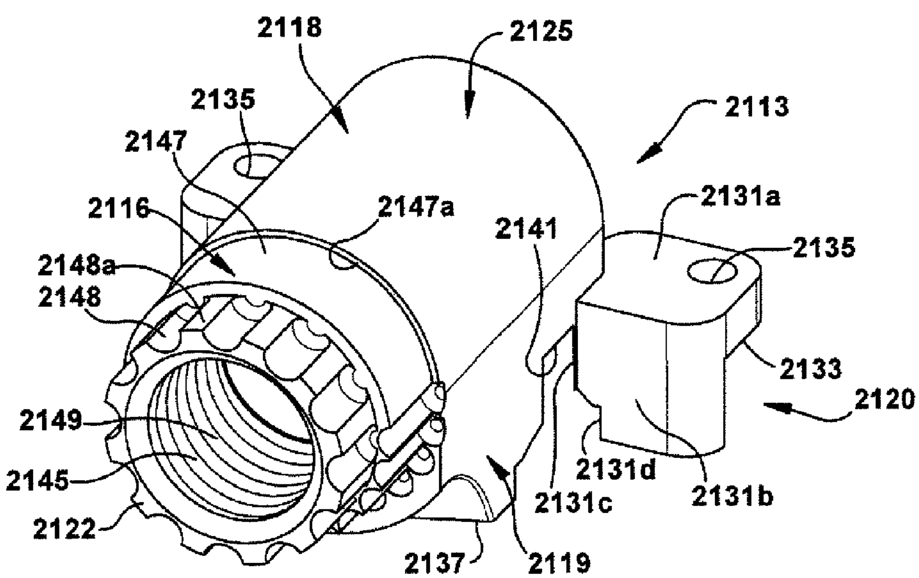
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Fig. 84

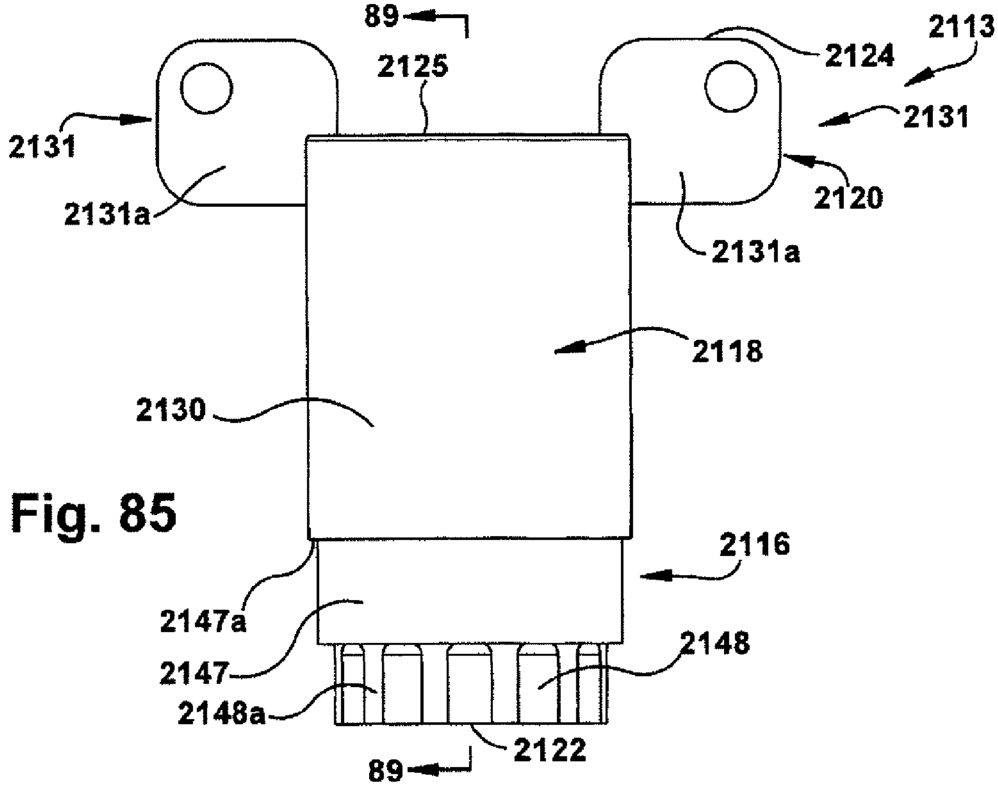
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Fig. 85

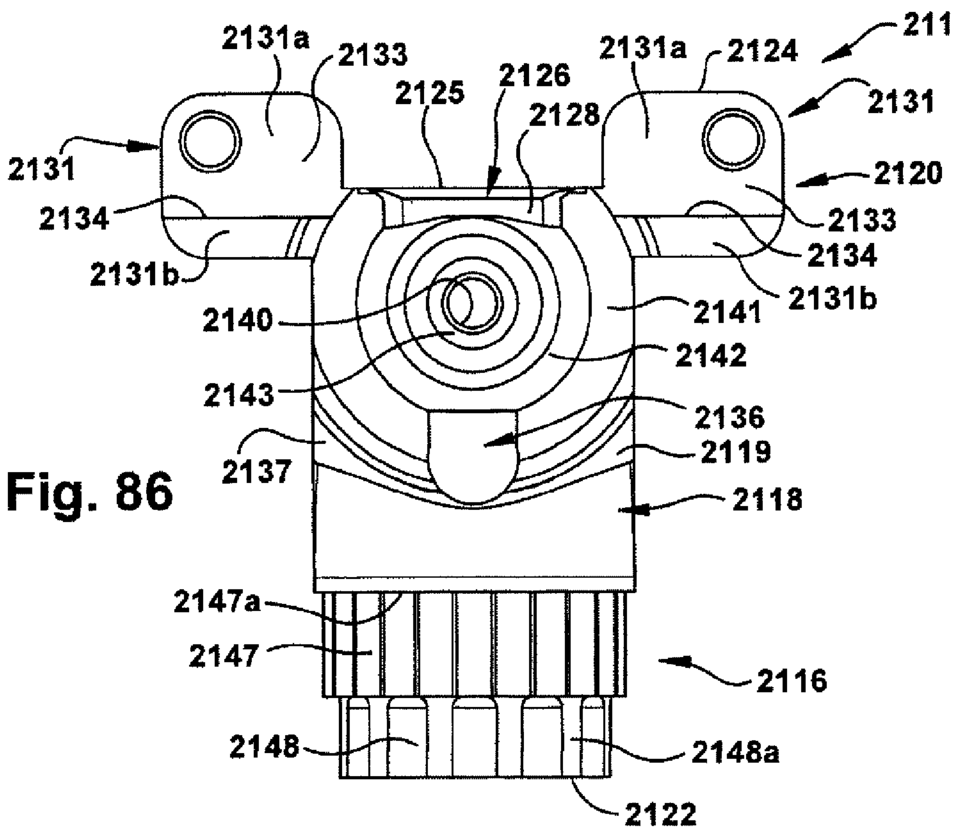
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Fig. 86

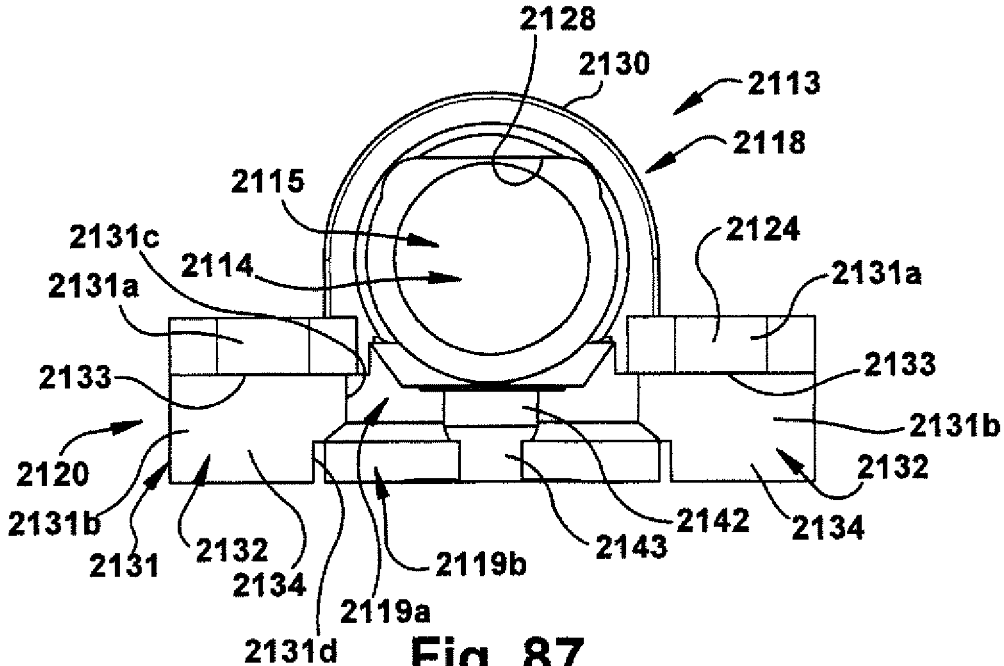
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Fig. 87

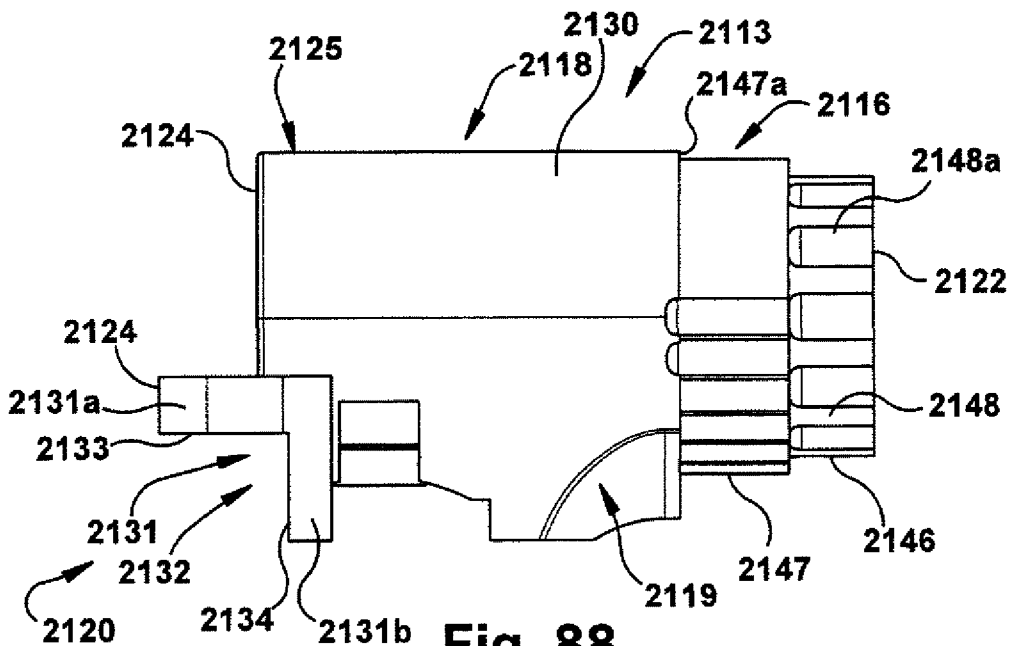
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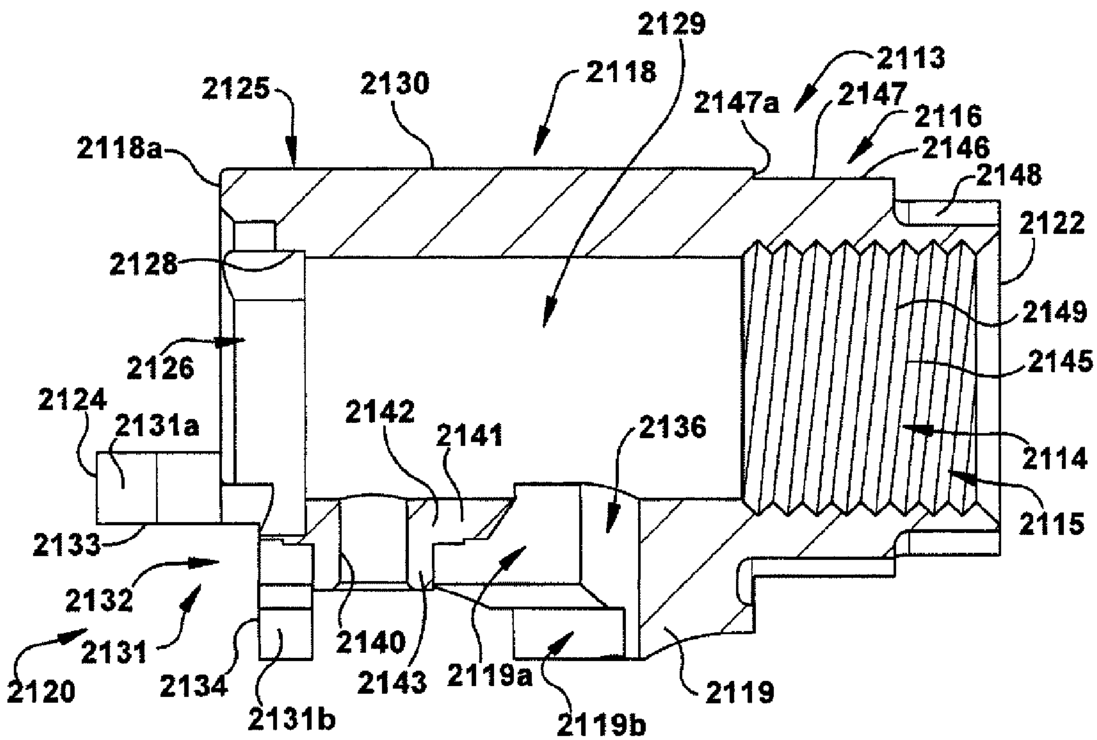
Fig. 88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2119b

Fig. 89

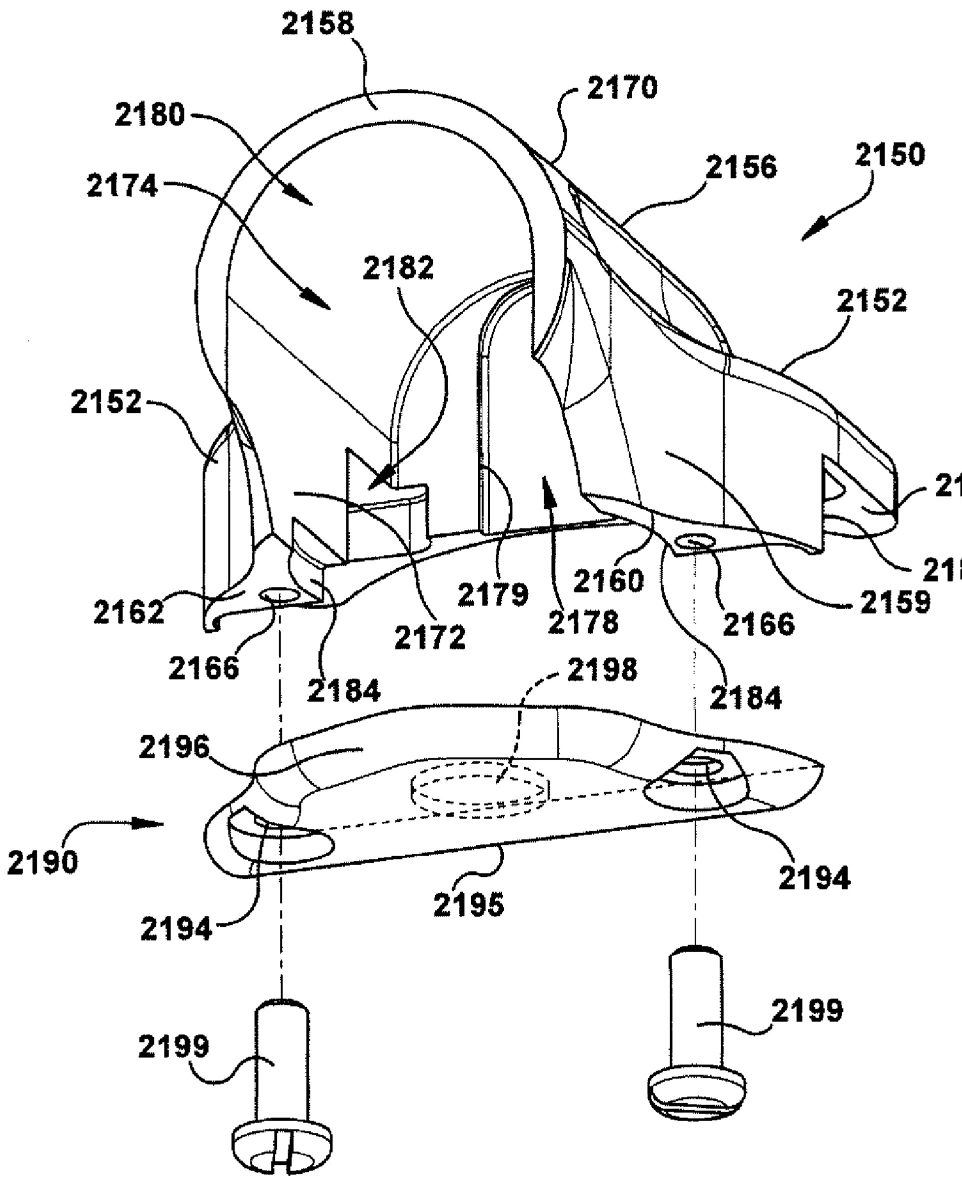
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Fig. 90

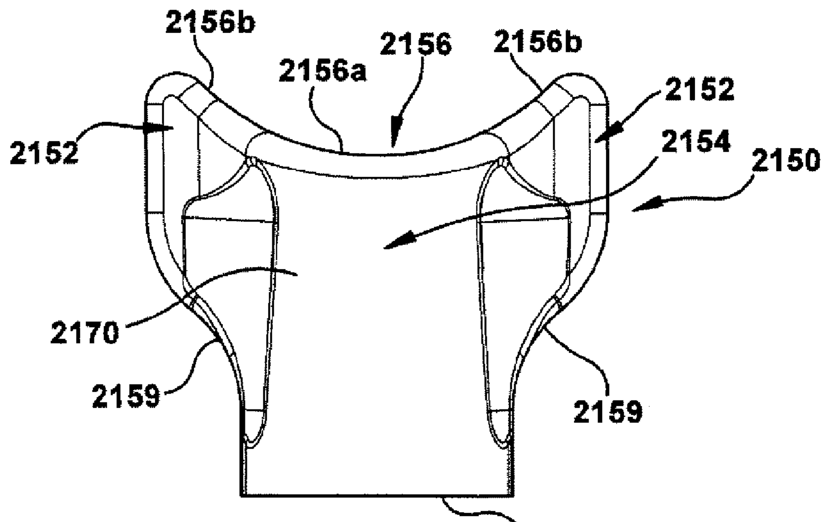


Fig. 91

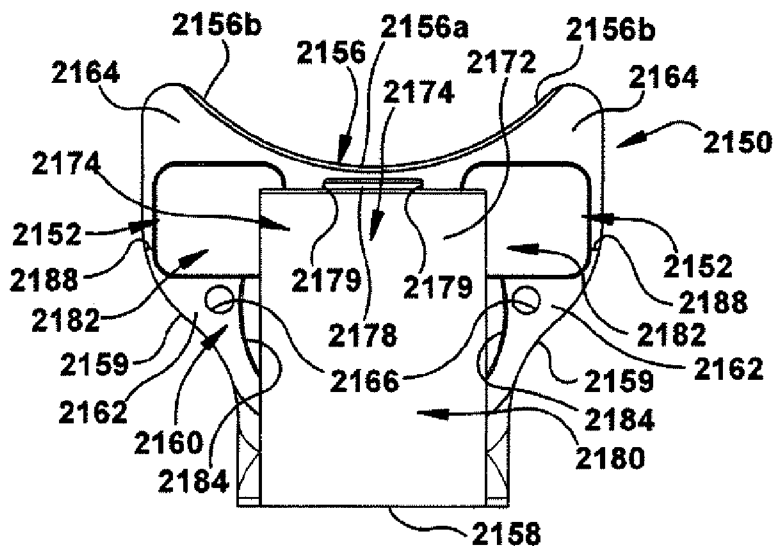


Fig. 92

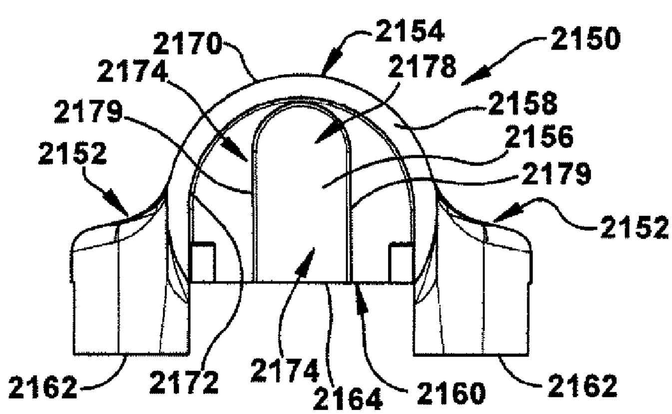


Fig. 93

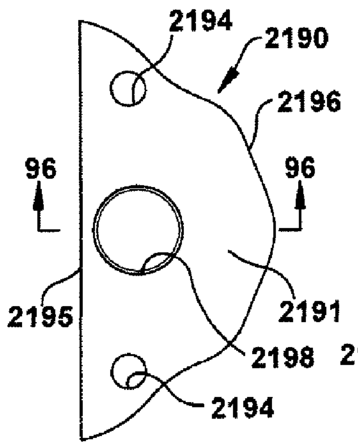


Fig. 94

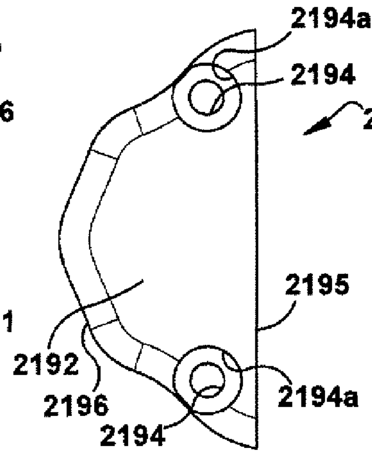


Fig. 95

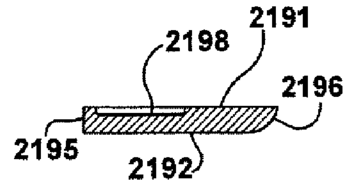


Fig. 96

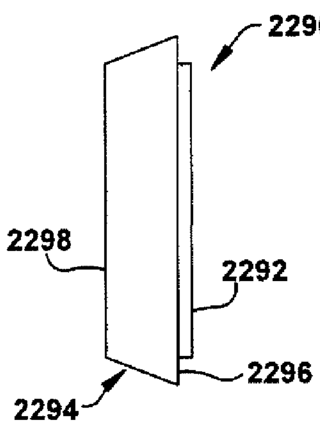


Fig. 97

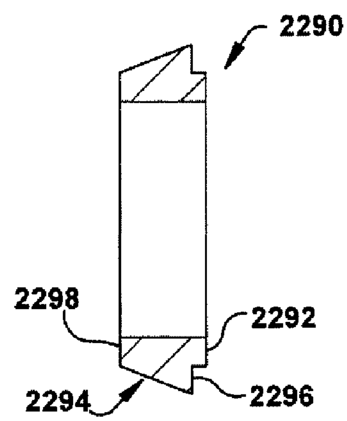


Fig. 98

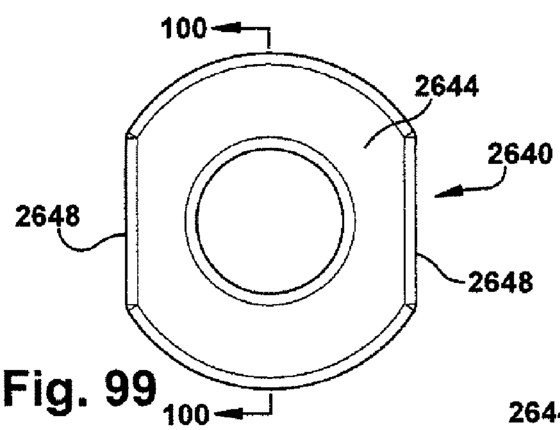


Fig. 99

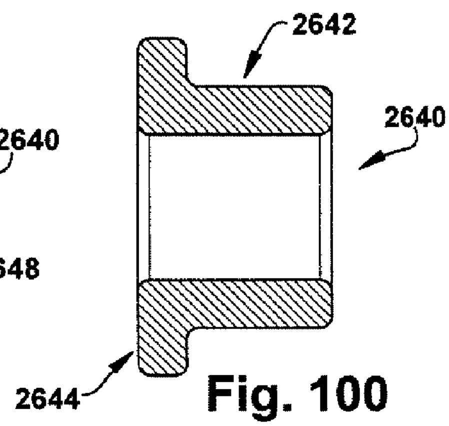
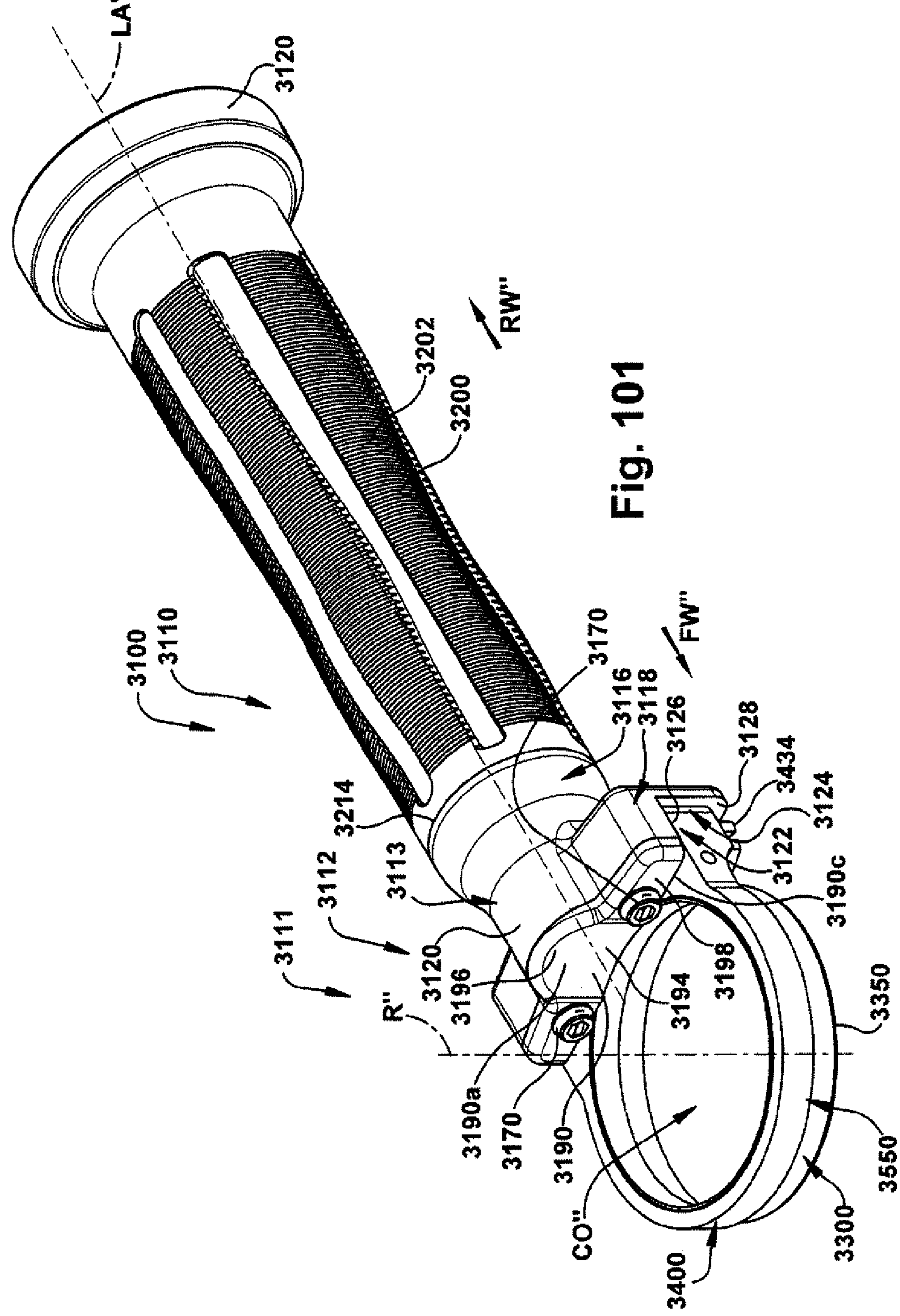


Fig. 100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CO"
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Fig. 101

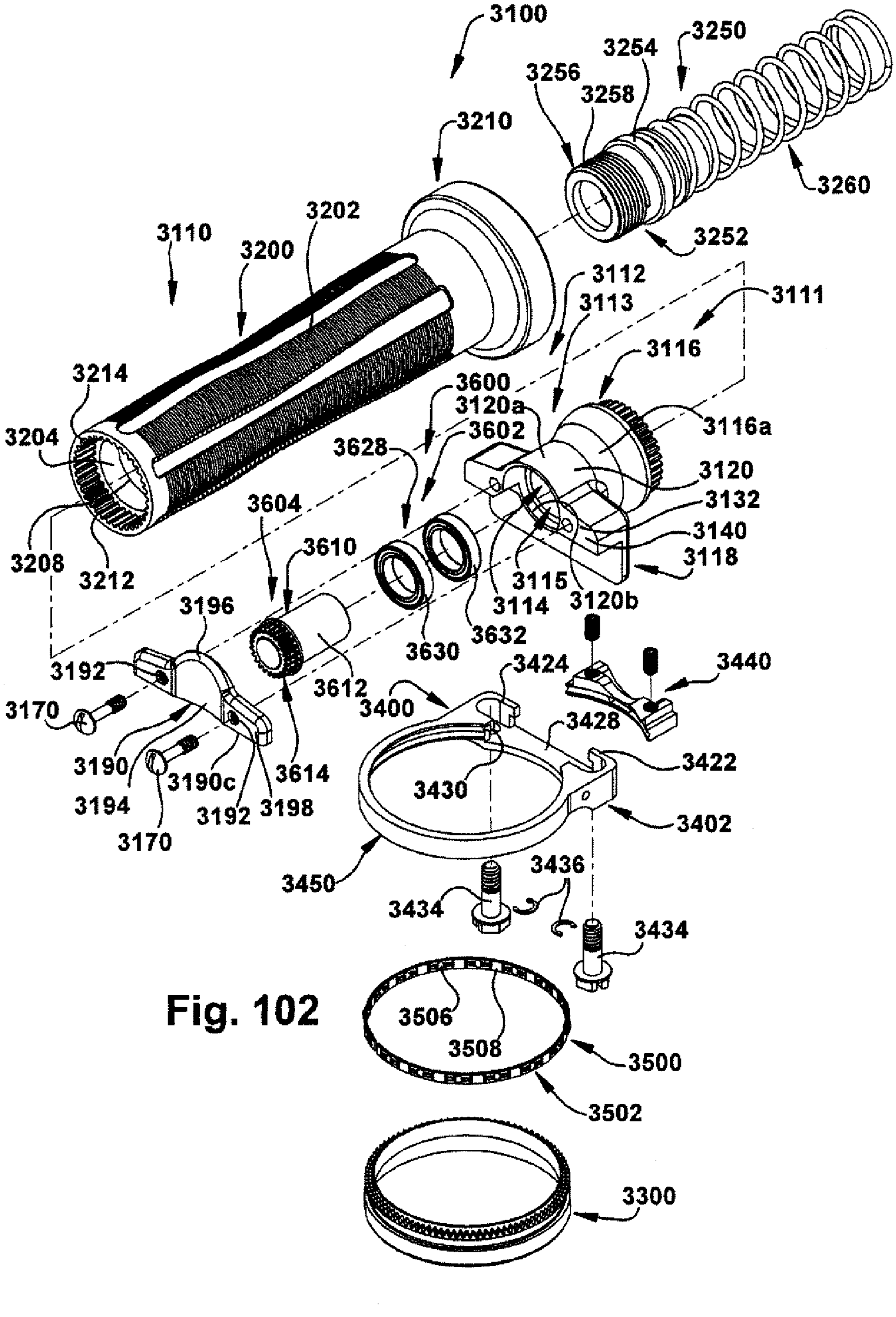
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Fig. 102

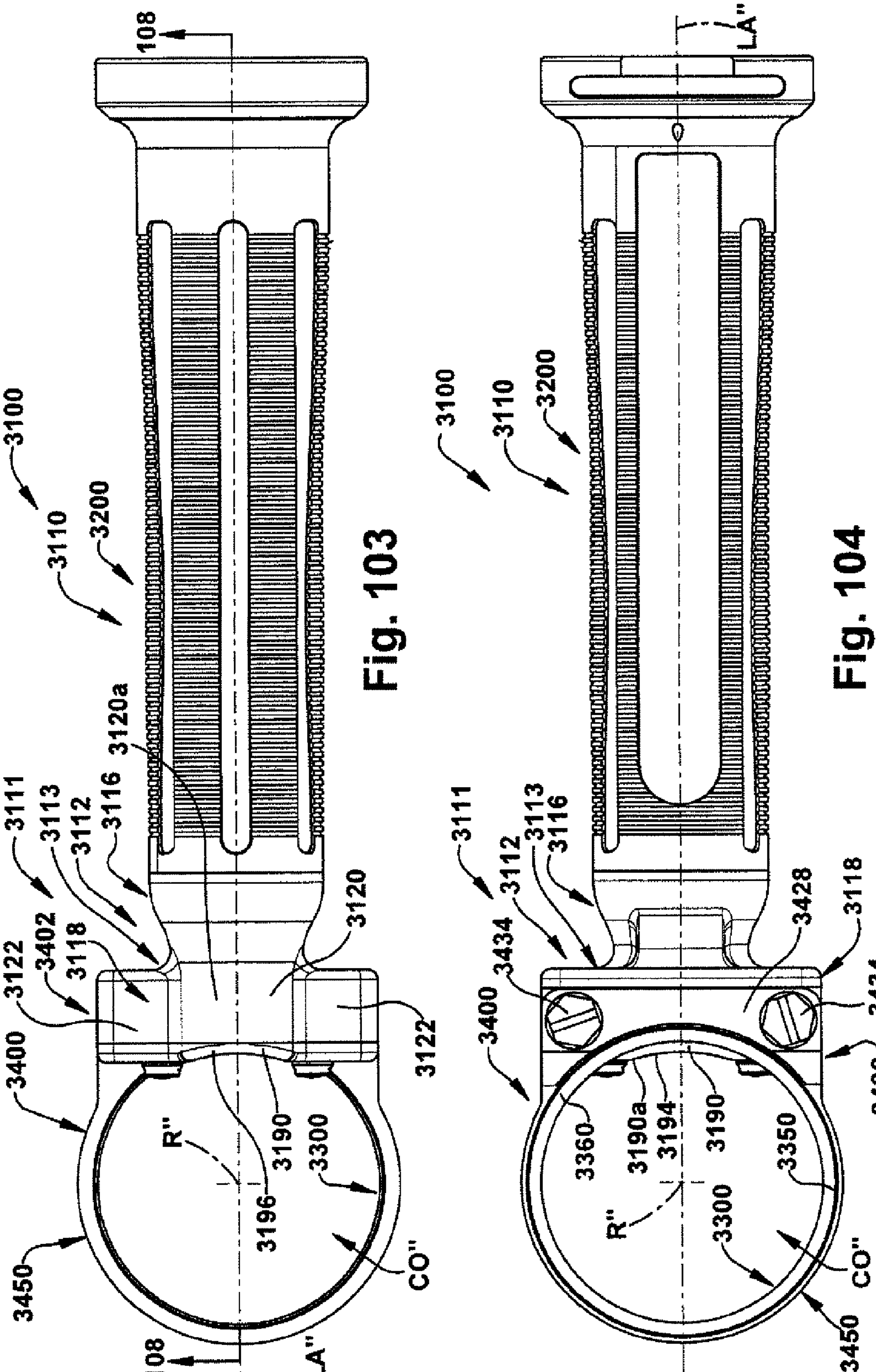
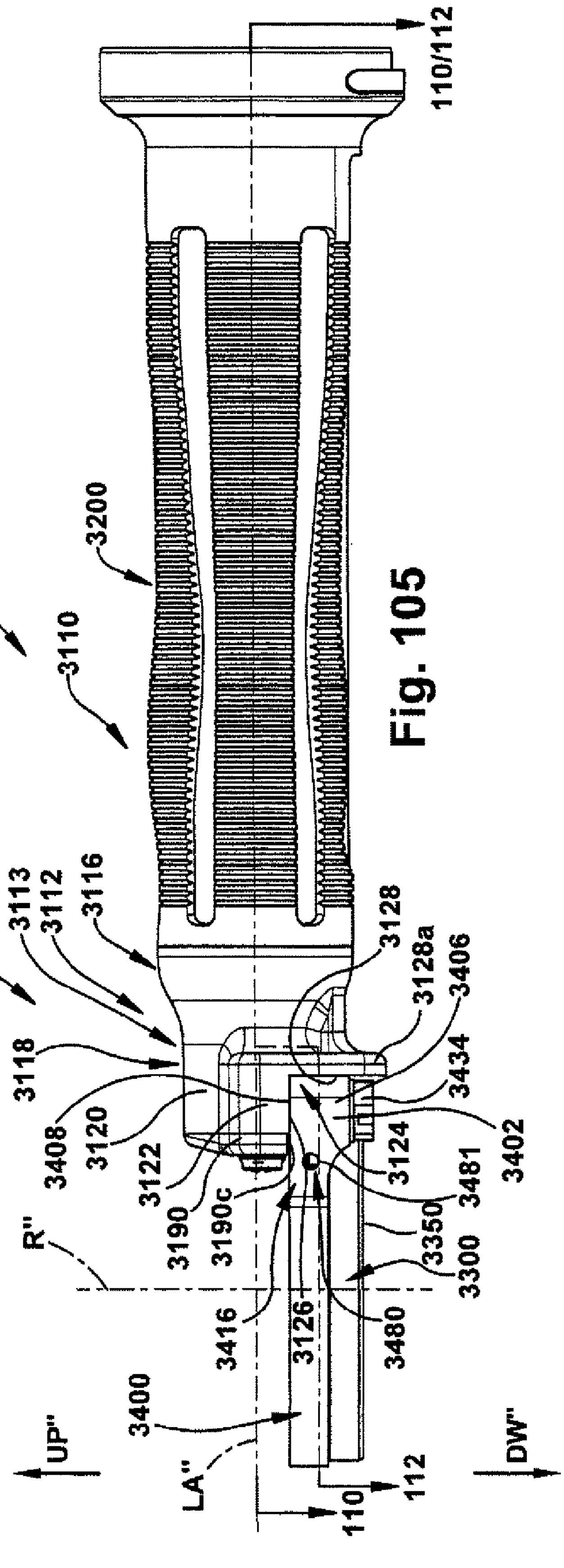


Fig. 103

Fig. 104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UP''
DW''
LA''
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Fig. 105

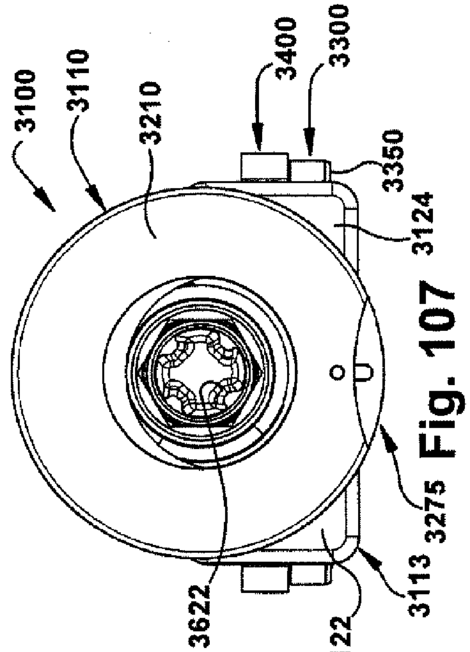


Fig. 107

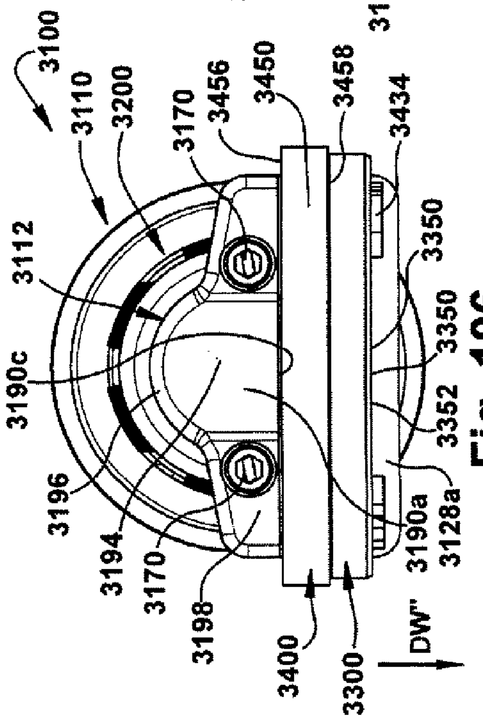


Fig. 106

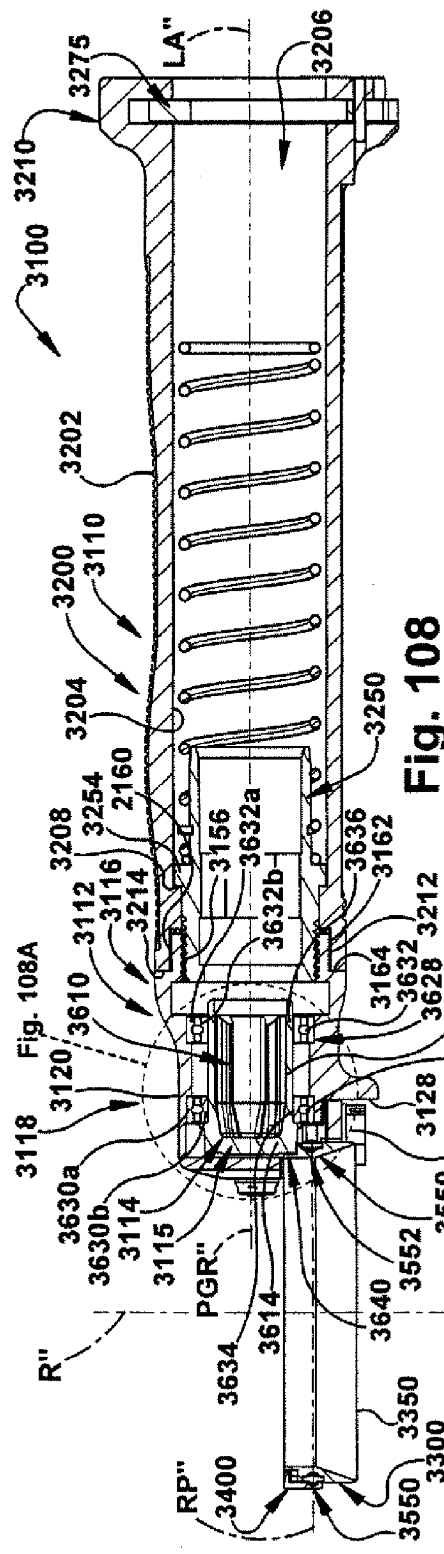
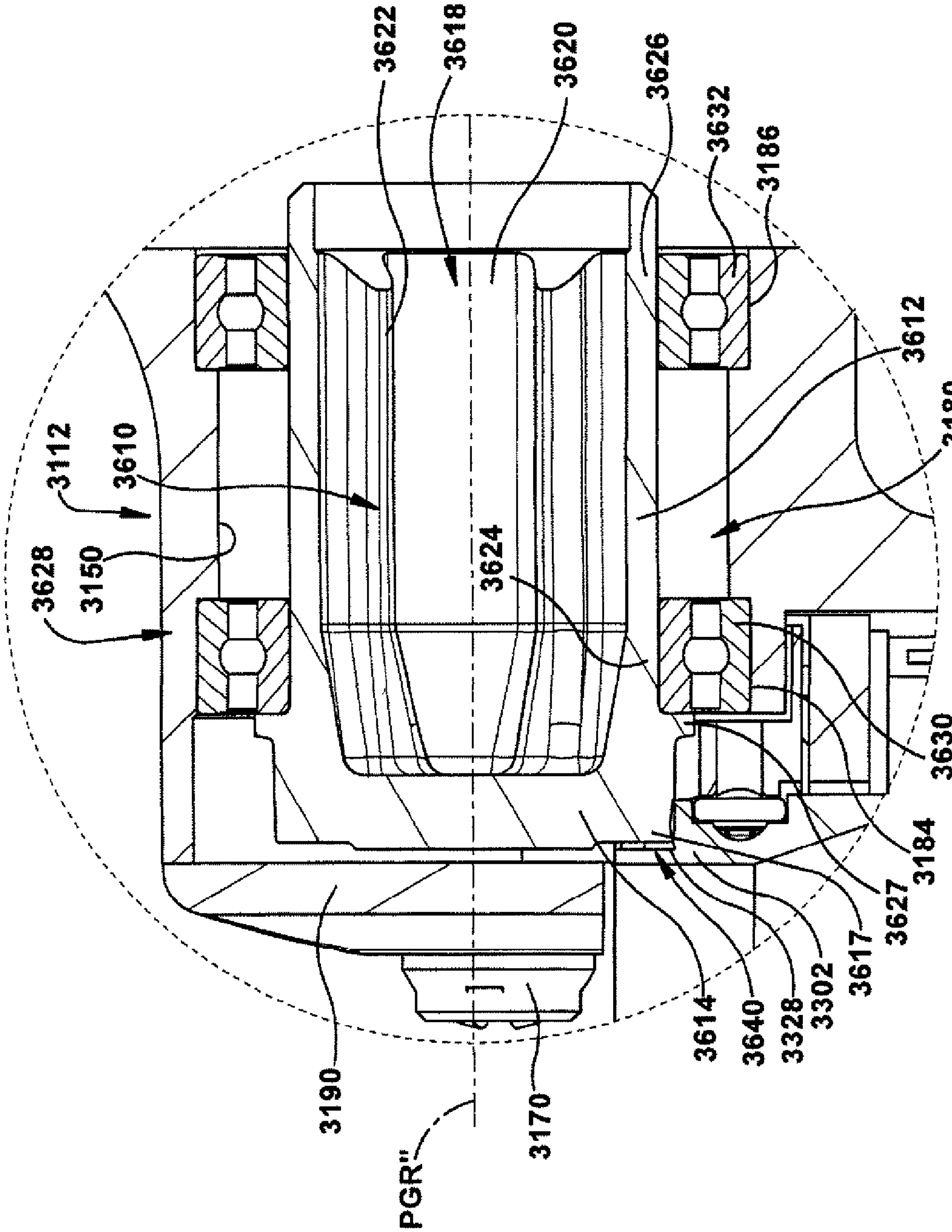


Fig. 108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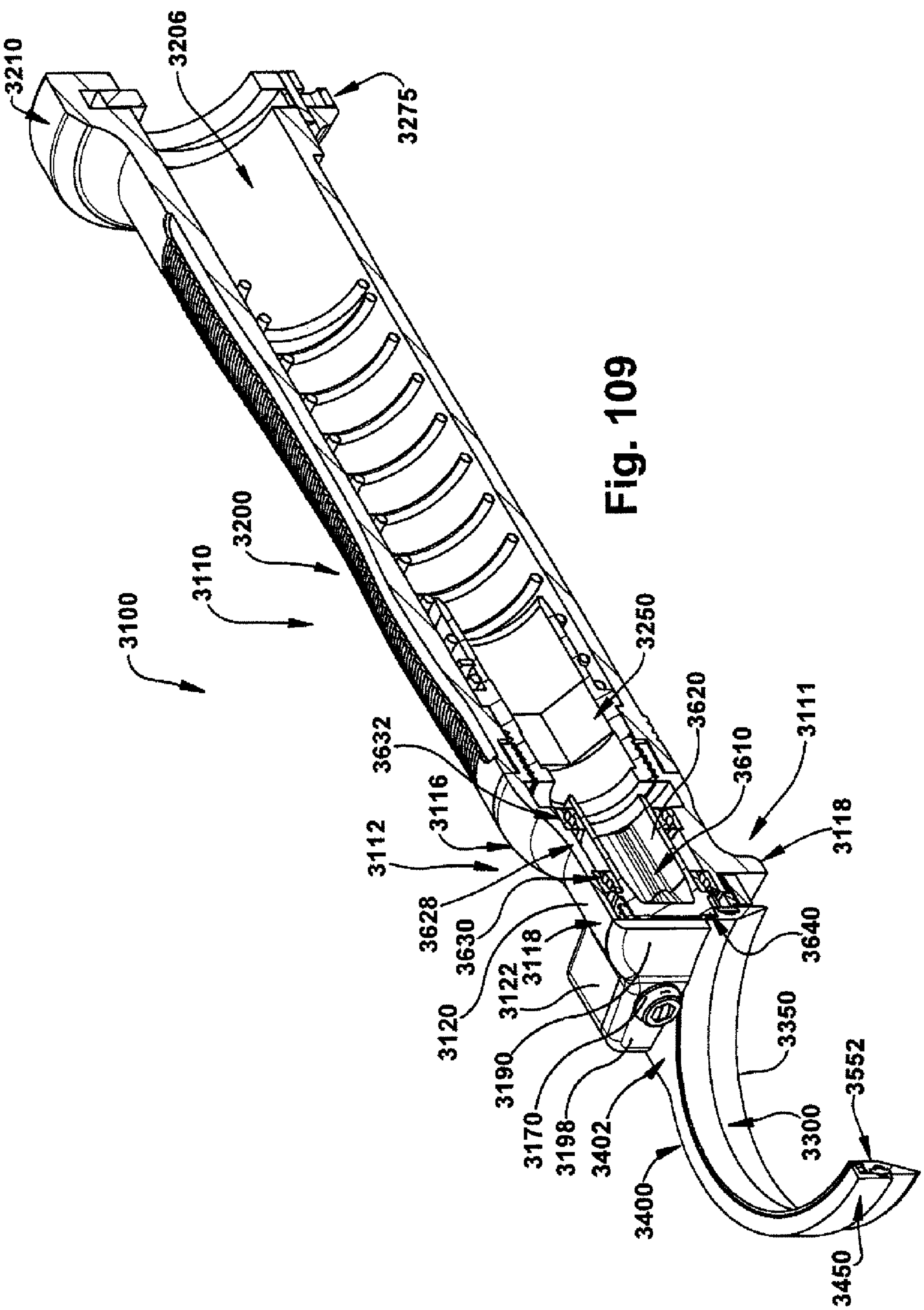
3190
3170
PGR''

Fig. 108A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3120
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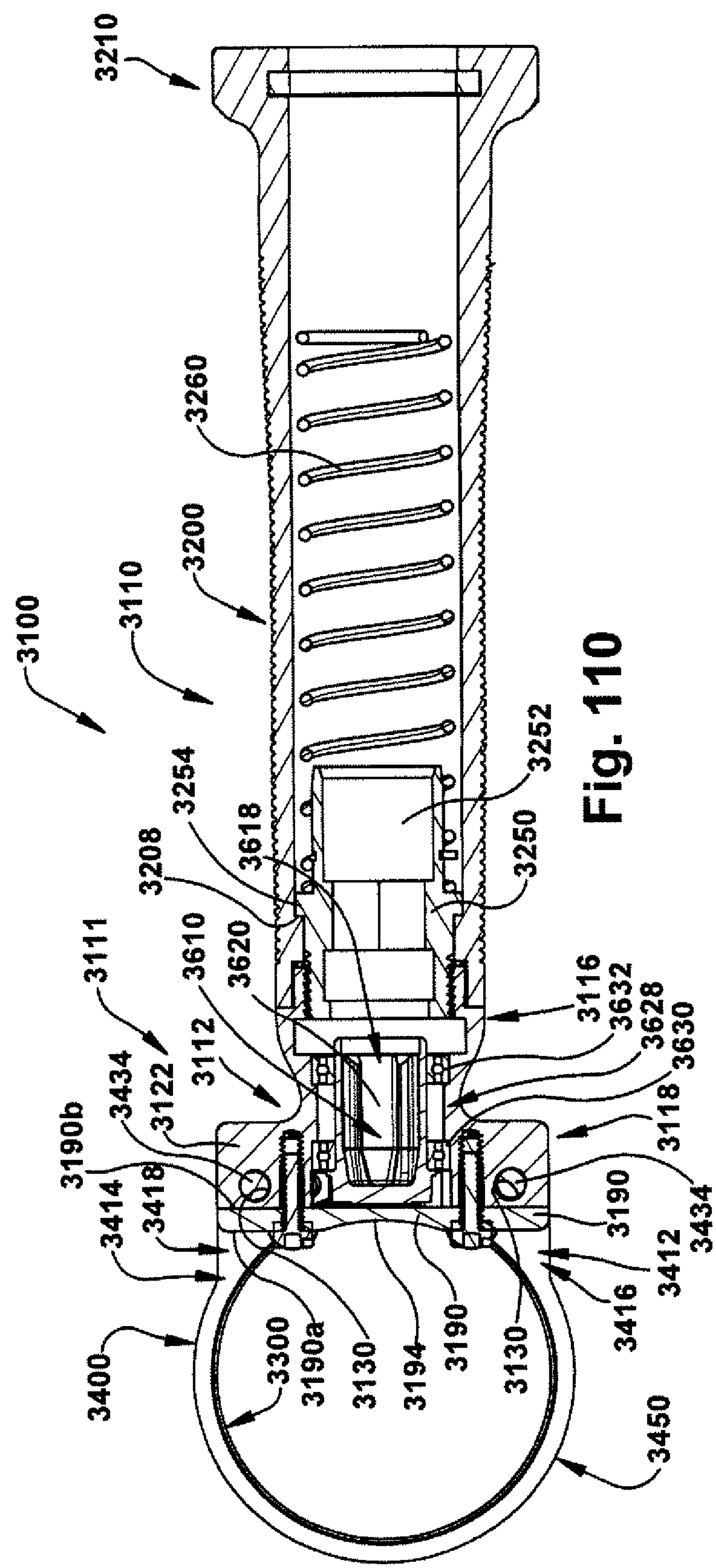
3190
3552
3170
3198
3402
3300
3400
3450

Fig. 109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3112
3434
3122
3118
3190b
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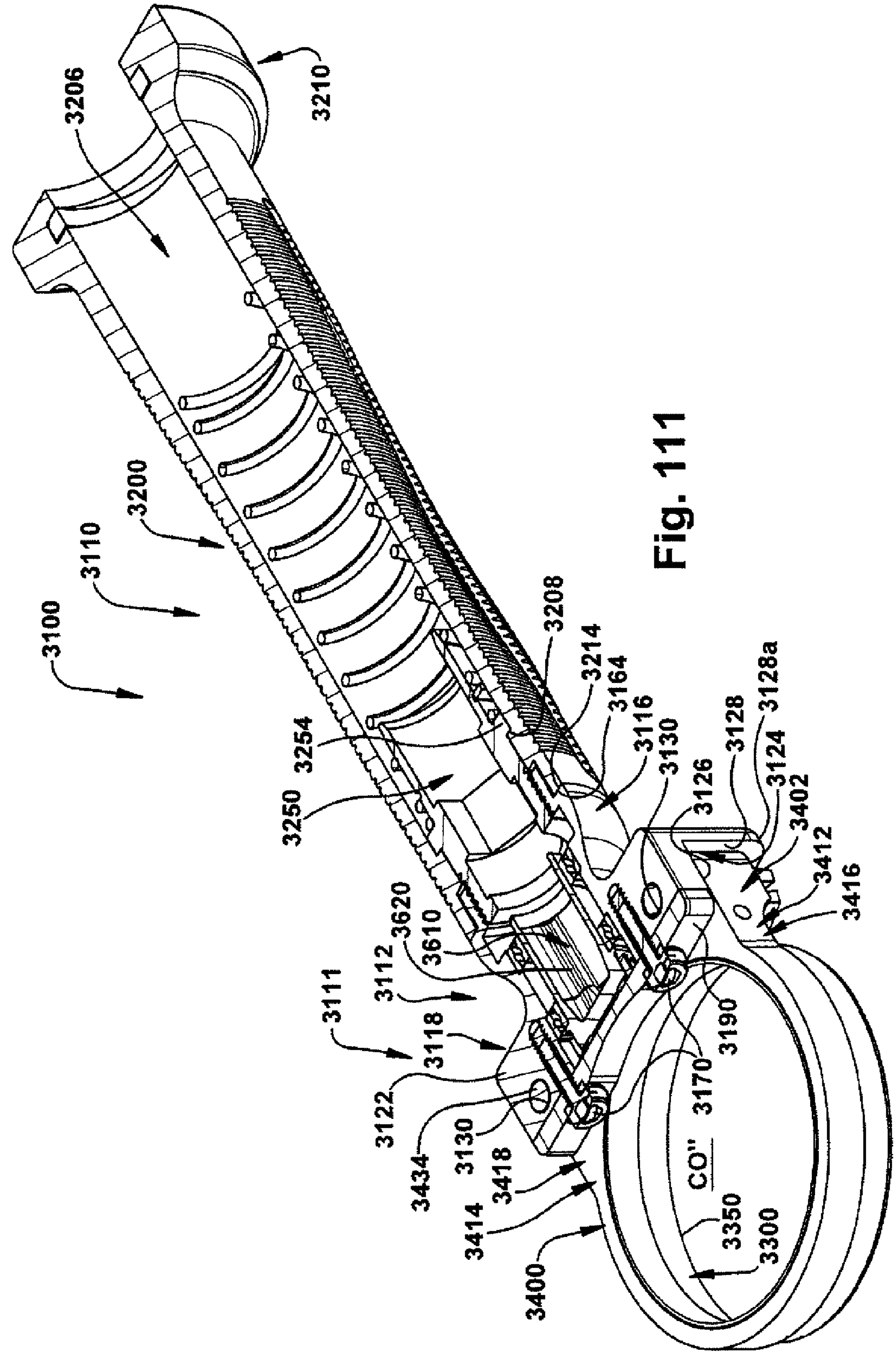
3416
3400
3300
3190a
3130
3194
3190
3130
3450

Fig. 110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3416
3254
3250
3620
3610
3112
3111
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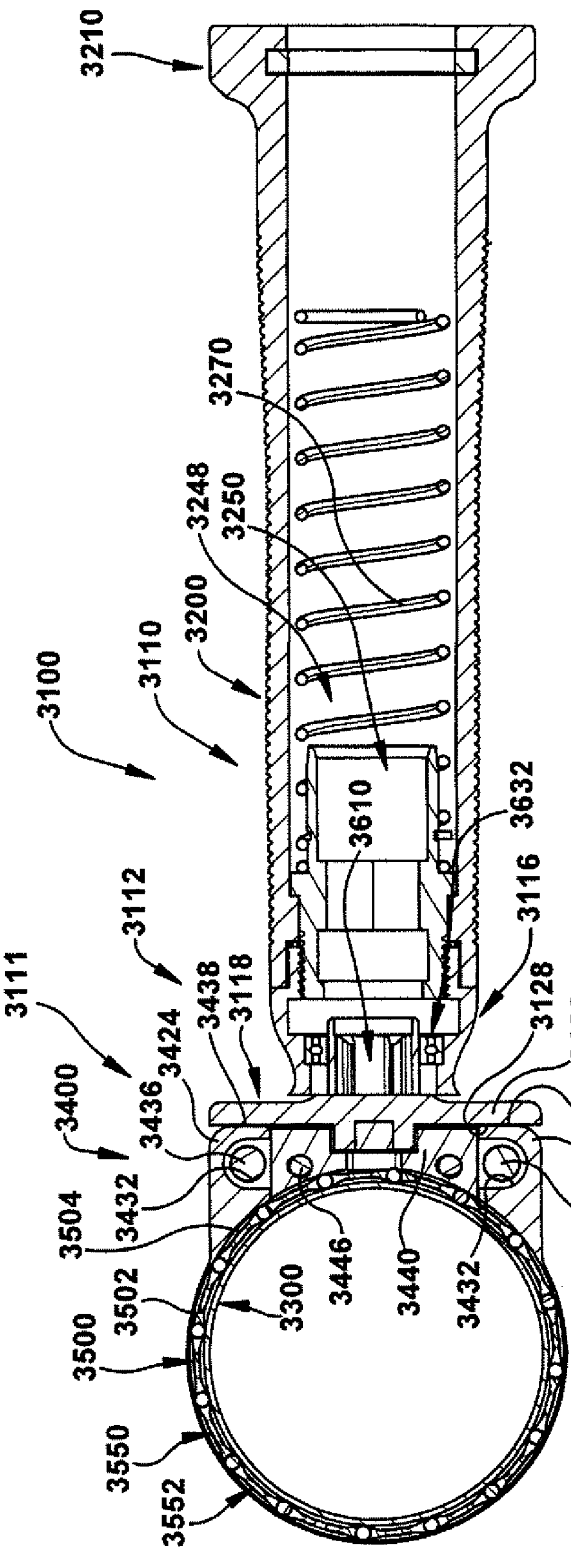
3122
3130
3434
3418
3414
3400
3190
3170
CO''
3350
3300

Fig. 111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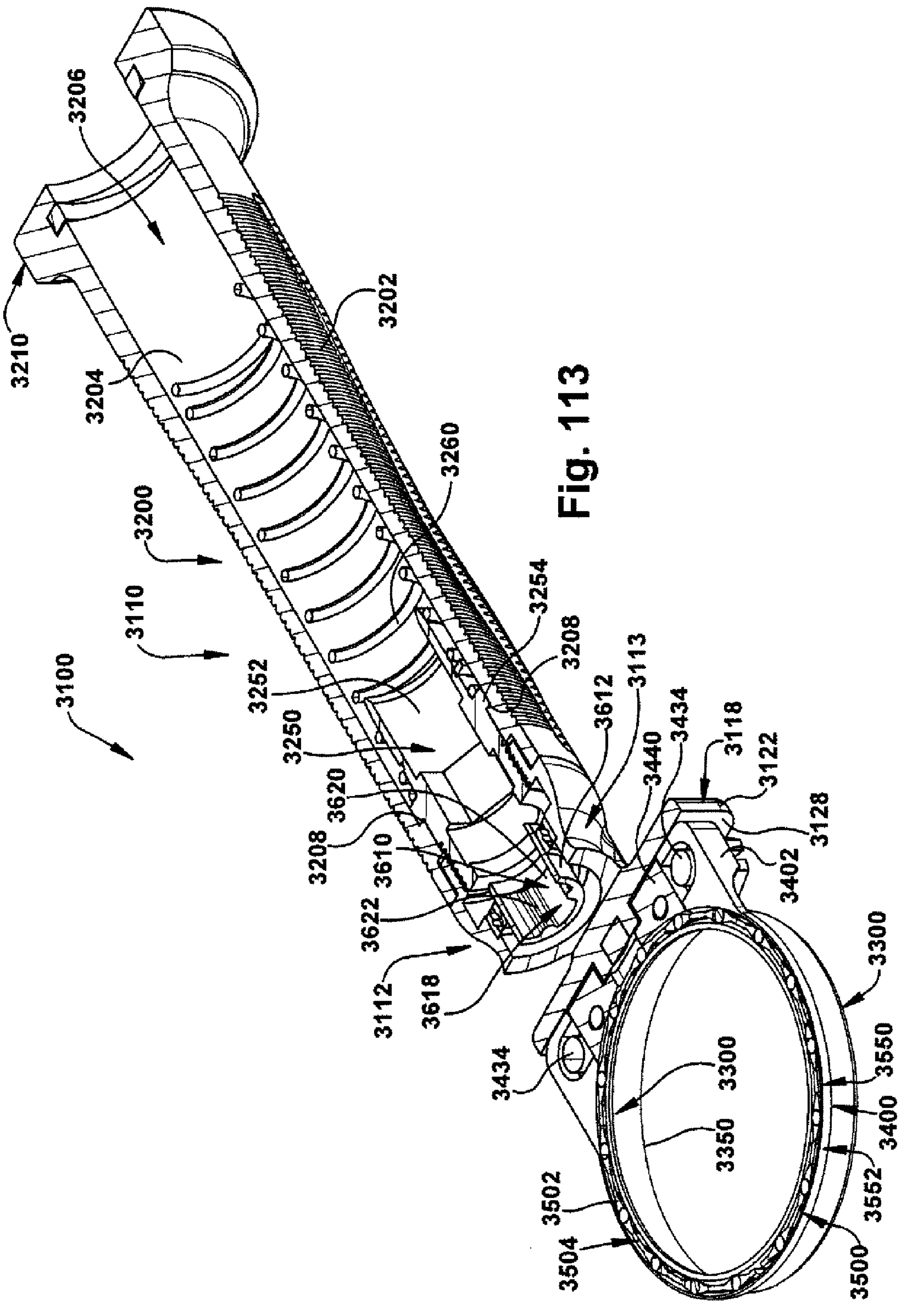
3500
3550
3552

Fig. 112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3612
3113
3112
3618
3440
3434
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3350
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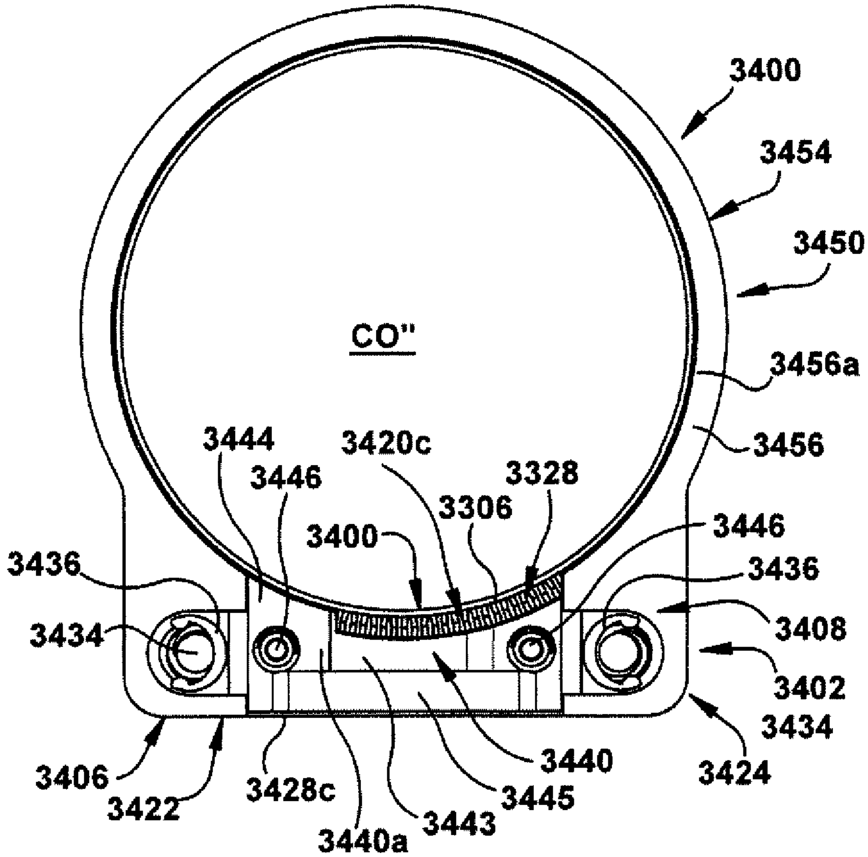
3550
3400
3552
3502
3504
3500

Fig. 113



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CO"
3456a
3456
3444
3420c
3446
3328
3306
3400
3446
3436
3436
3408
3434
3402
3434
3406
3422
3428c
3440a
3443
3445
3440
3424

Fig. 114

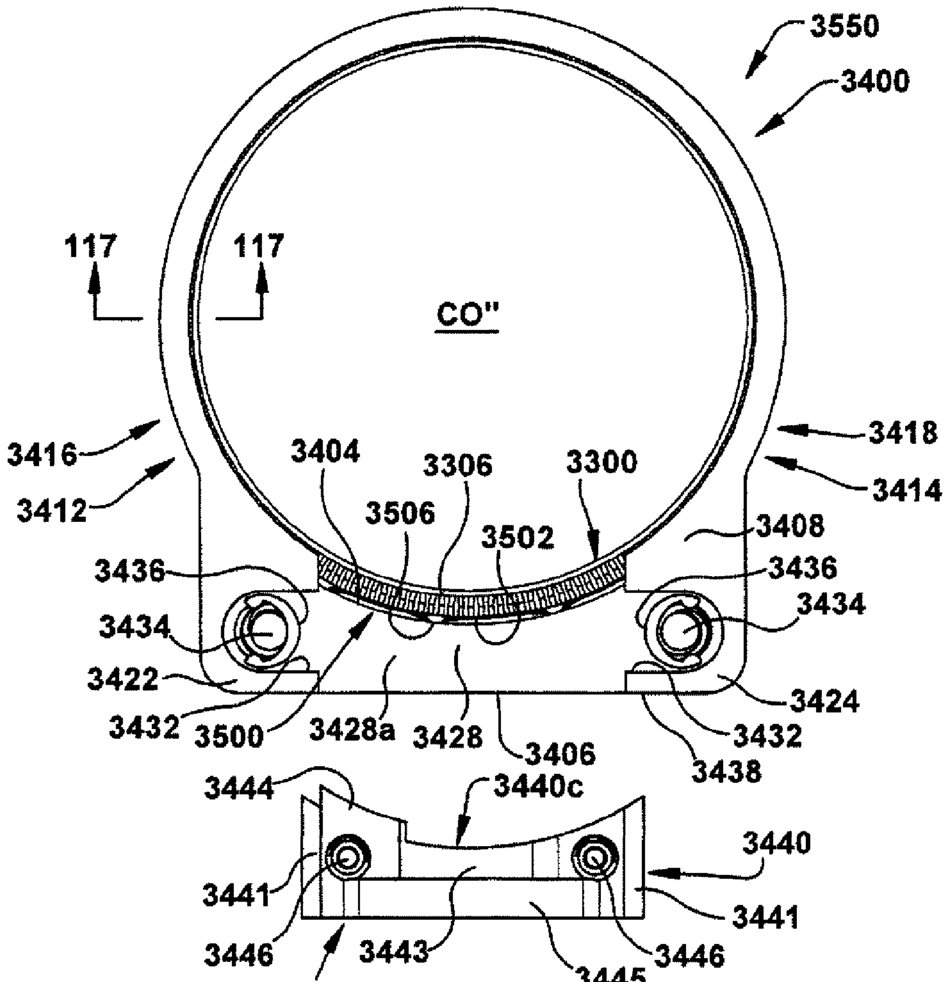


Fig. 115

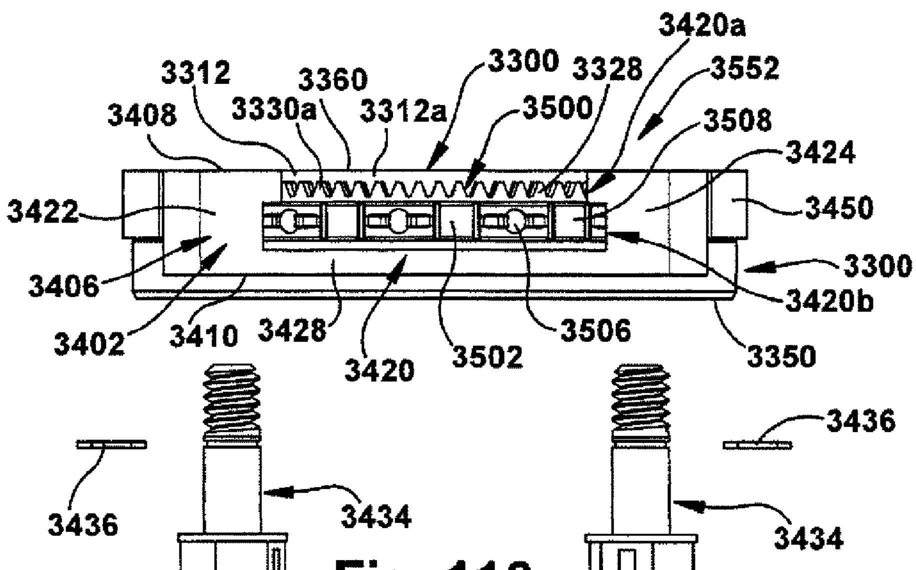
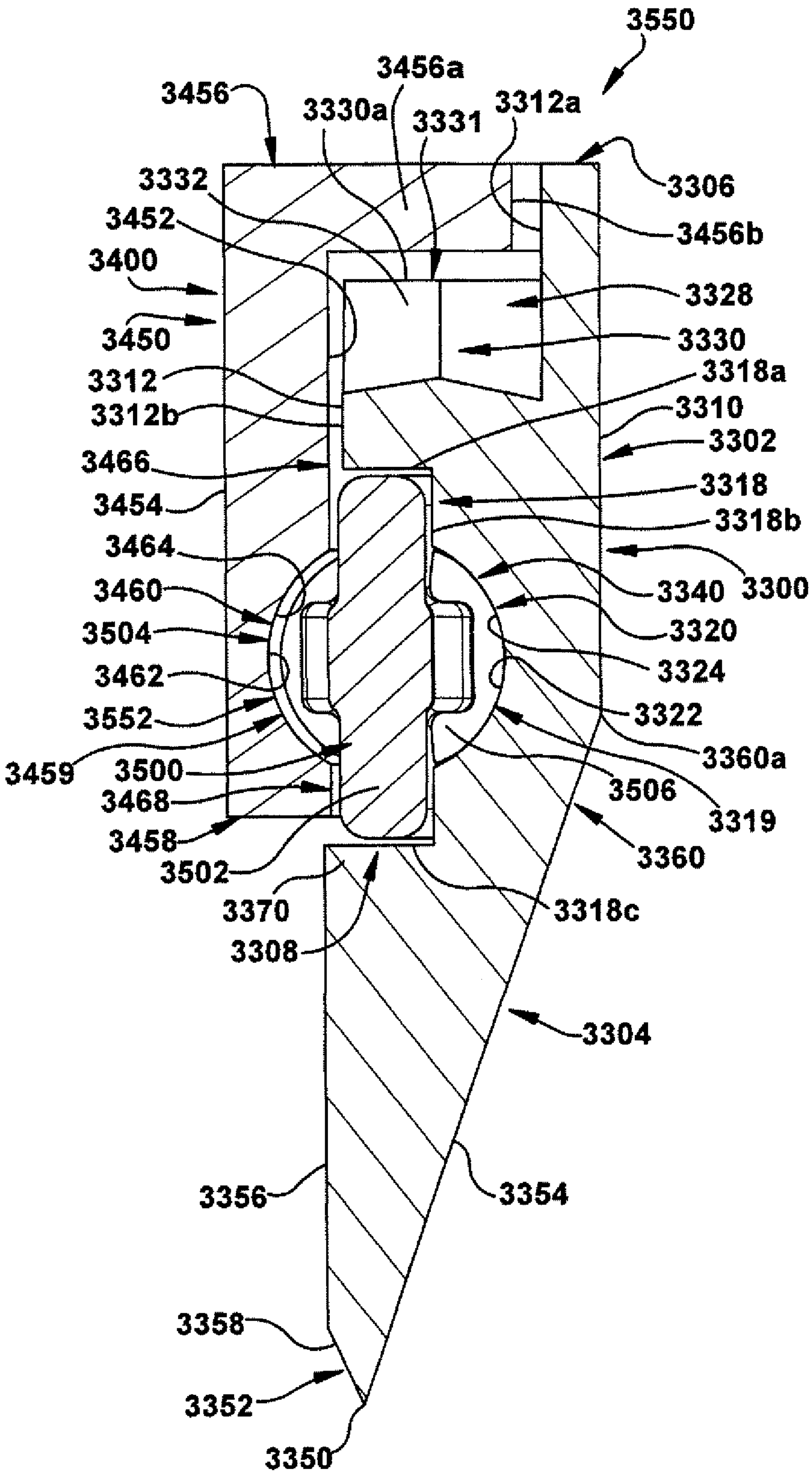


Fig. 116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3318a
3312b
3310
3302
3466
3318
3454
3318b
3464
3300
3340
3460
3320
3504
3324
3462
3322
3552
3360a
3459
3500
3506
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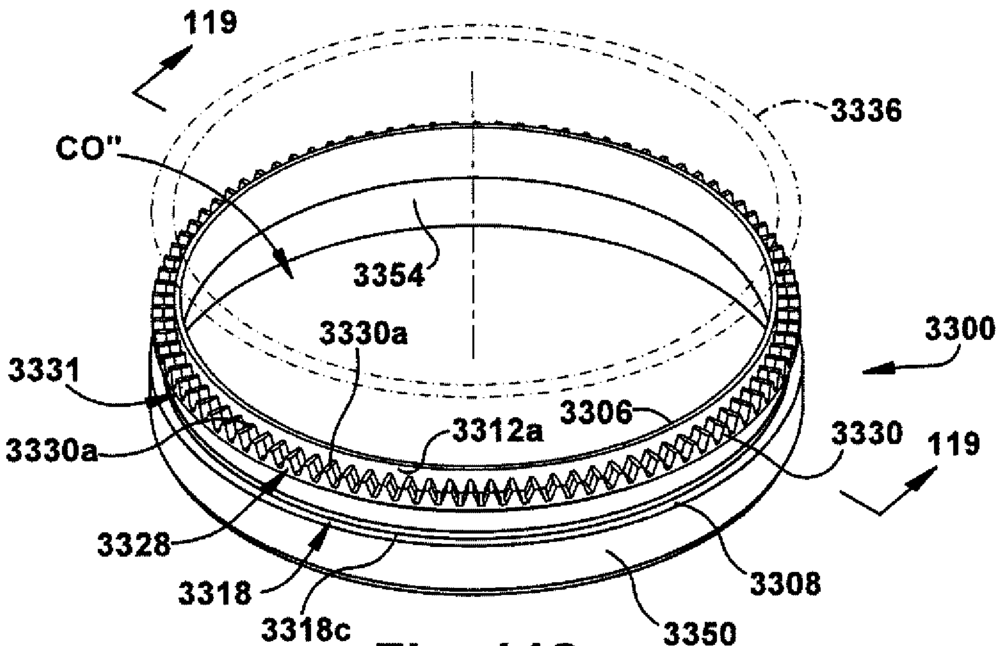
3502
3370
3318c
3308
3304
3356
3354
3358
3352
3350

Fig. 117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CO"
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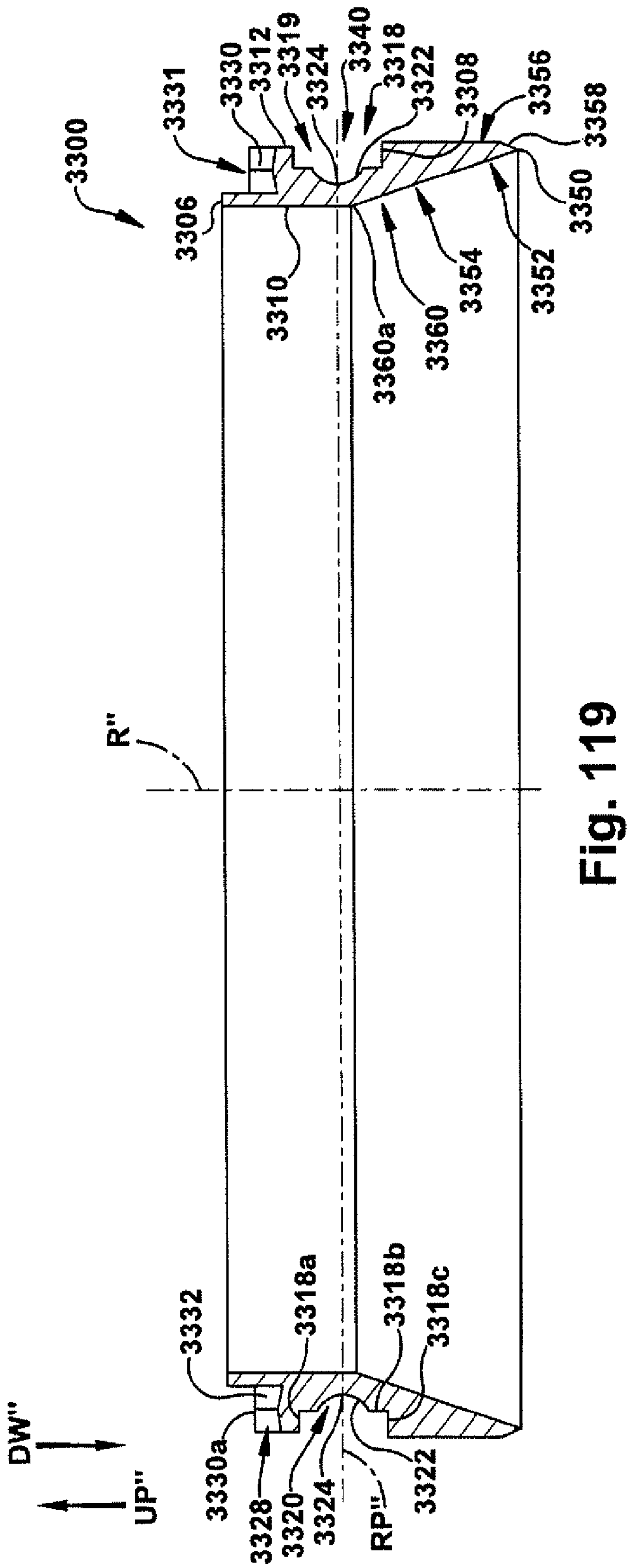
3330
119
3312a
3330a
3328
3308
3318
3318c
3350

Fig. 118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3306
3331
3330
3312
3319
3324
3340
3318
3322
3308
3356
3358
3350
3352
3354
3360
3360a
3310
R''
3332
3318a
3318b
3318c
3330a
3328
3320
3324
RP''
3322
DW''
UP''

Fig. 119

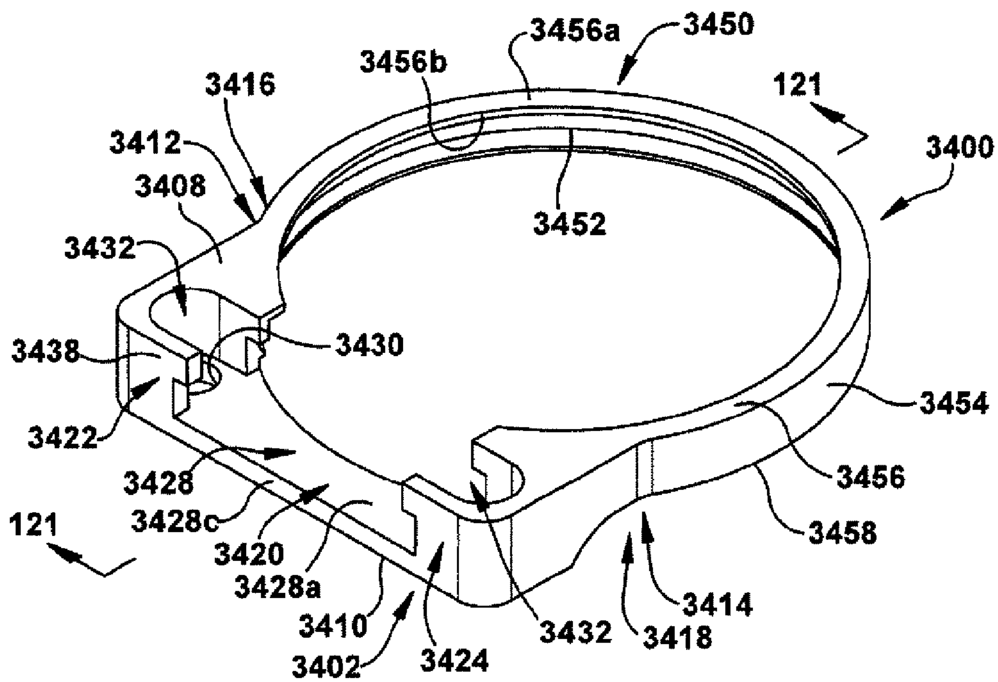


Fig. 120

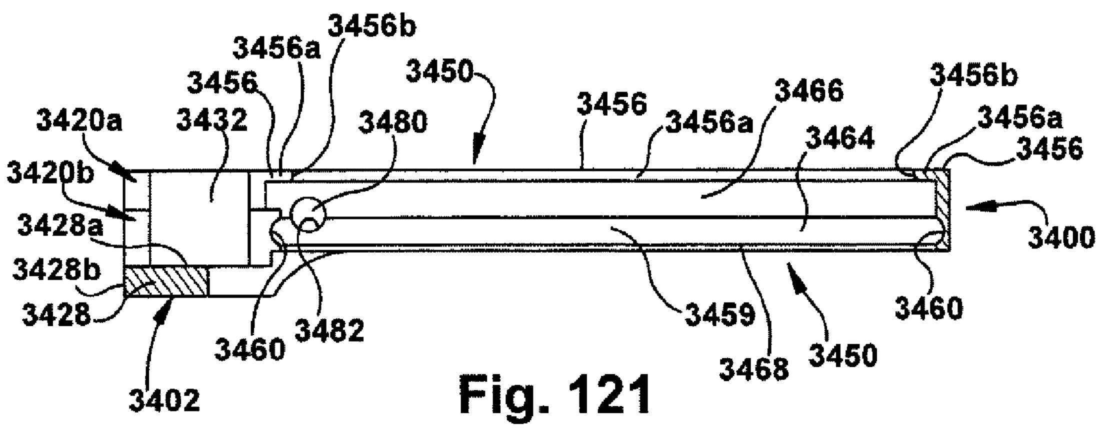
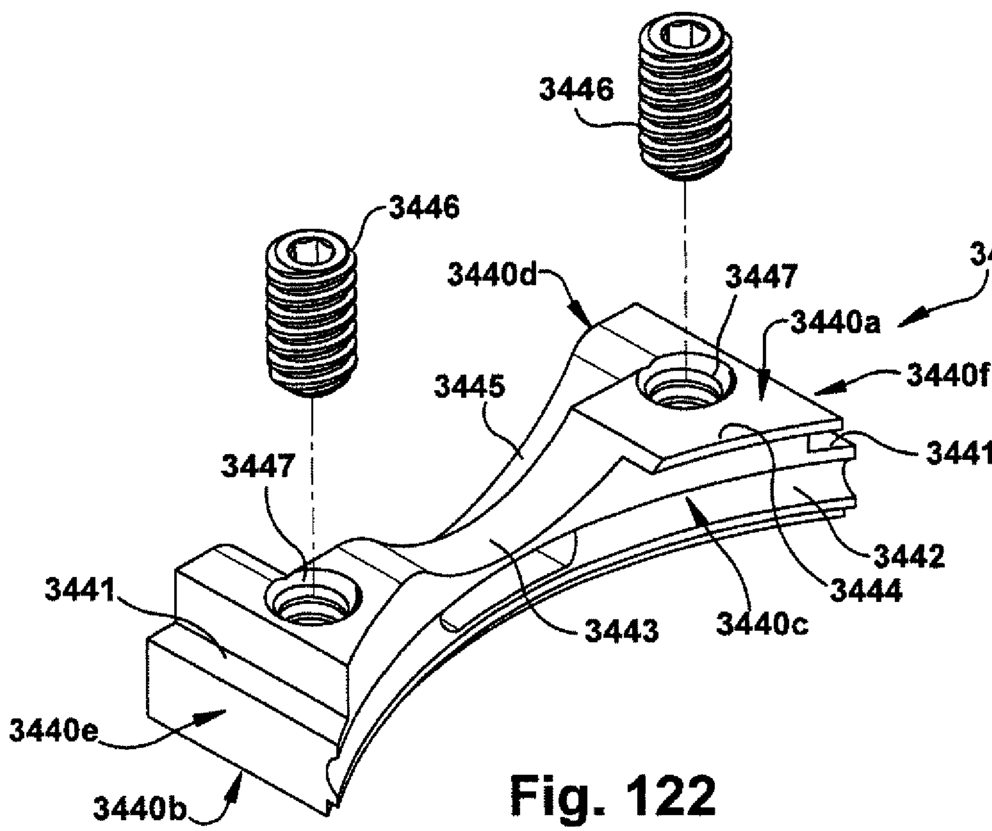


Fig. 121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3441
3447
3442
3441
3444
3443
3440c
3440e
3440b

Fig. 122

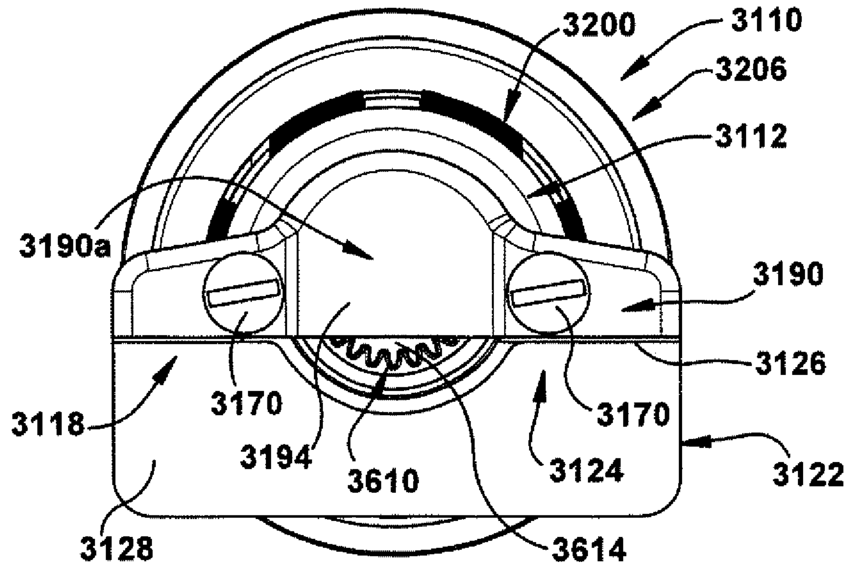


Fig. 123

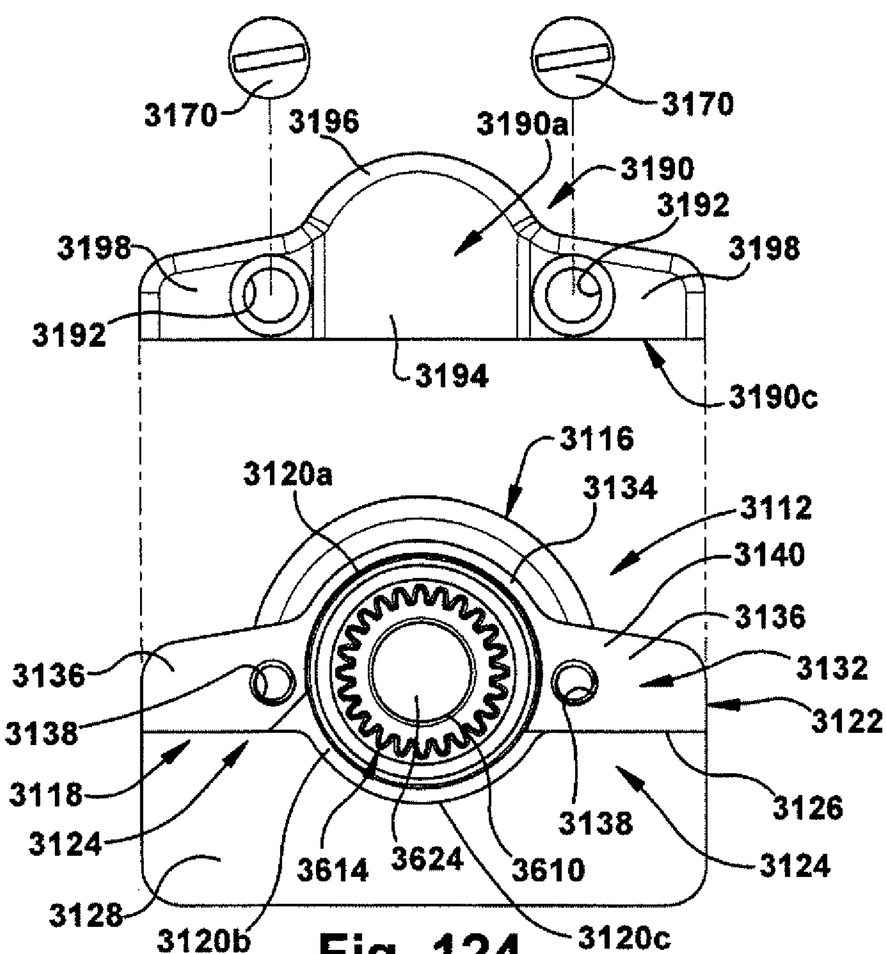


Fig. 124

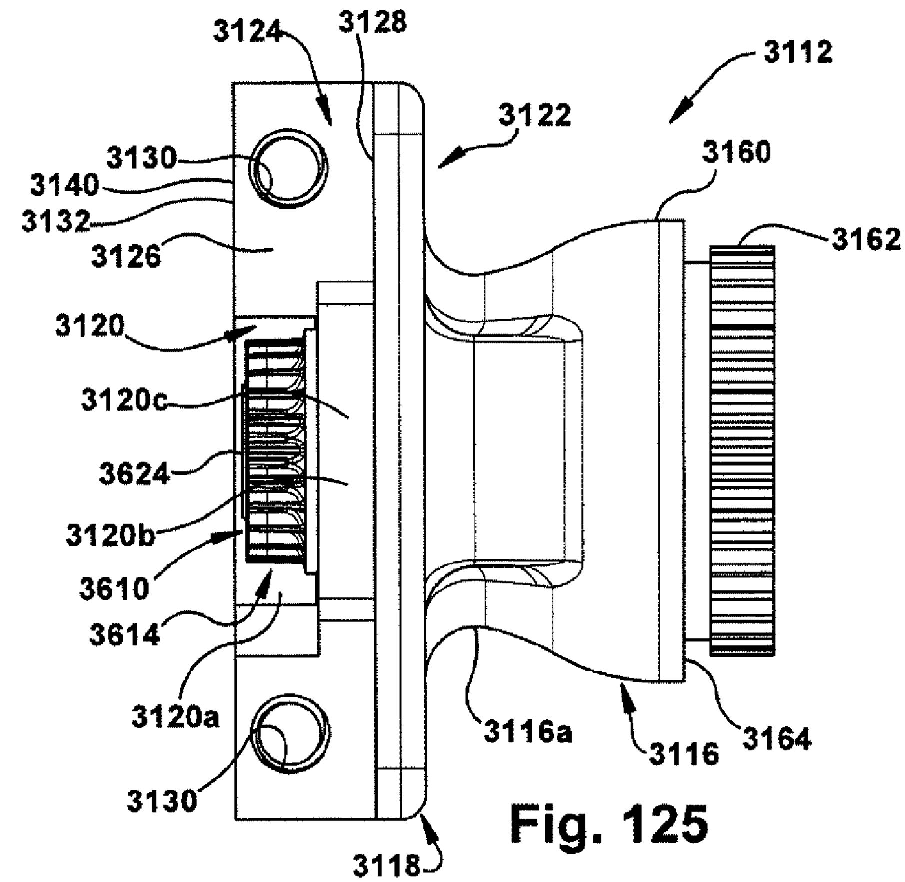


Fig. 125

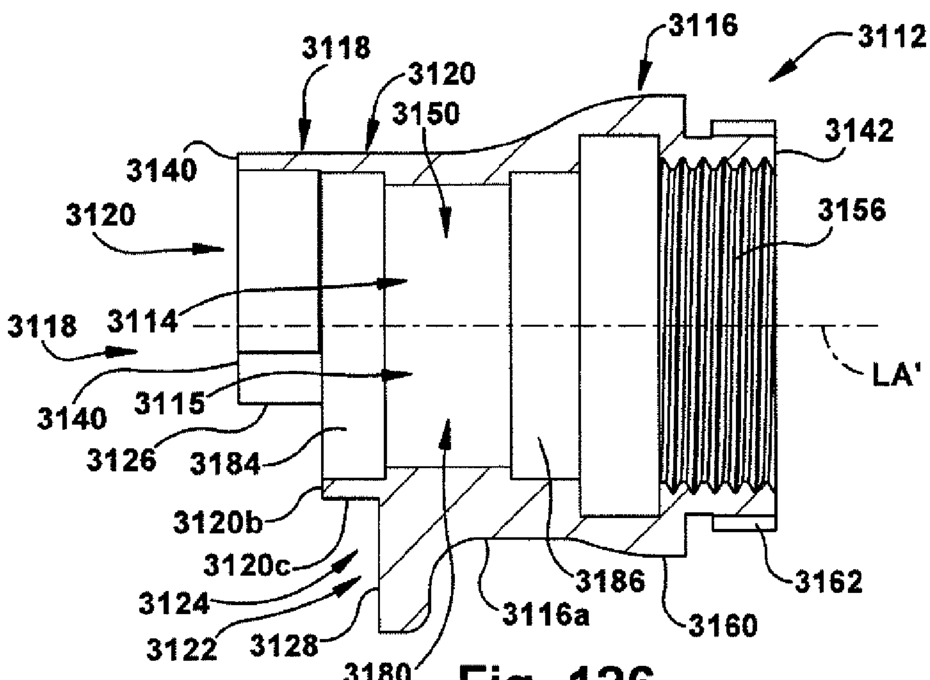


Fig. 126

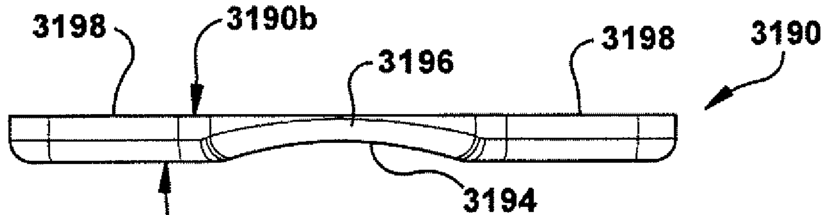


Fig. 127

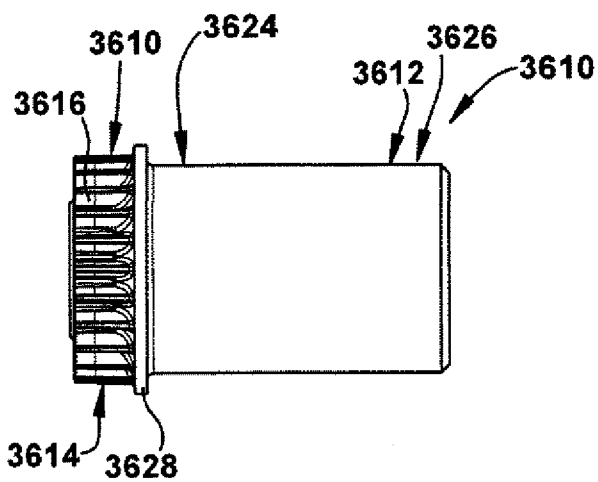


Fig. 128

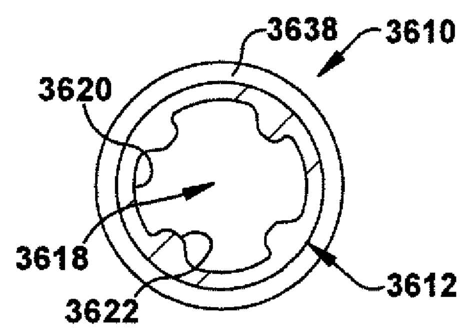
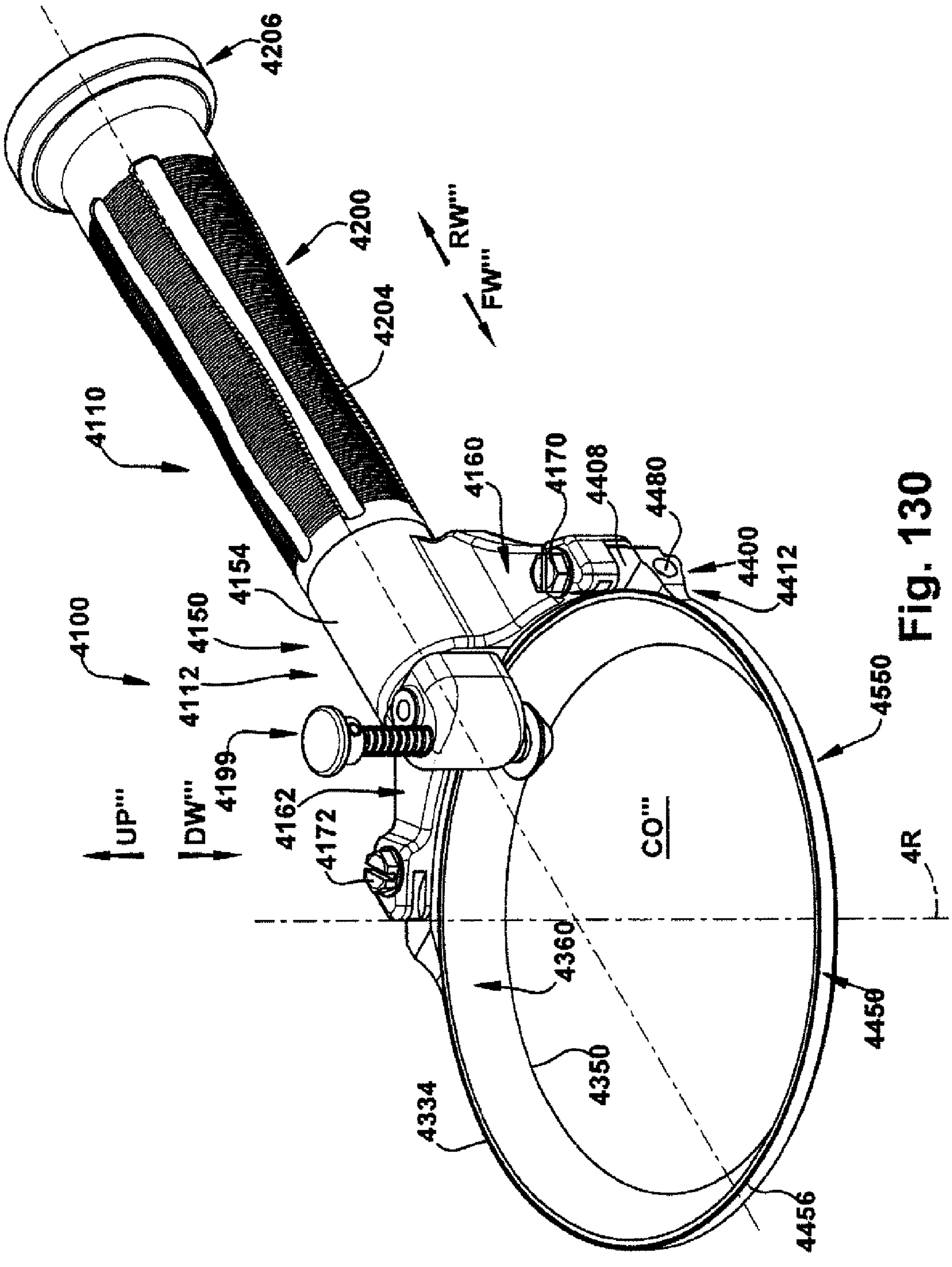


Fig. 129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4154
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4100
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4199
4162
4172
UP'''
DW'''
CO'''
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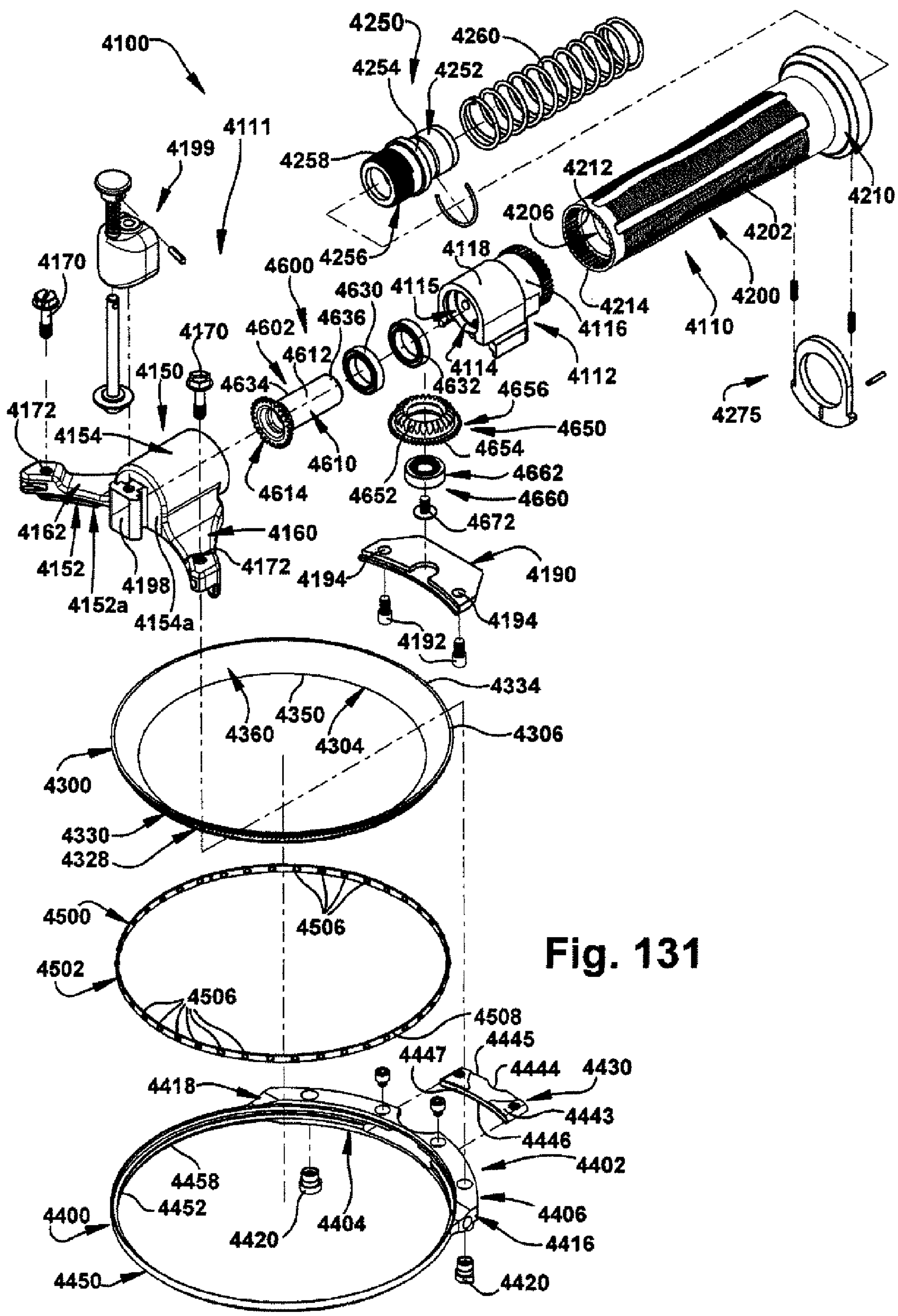
4R
4360
4450
4350
4334
4456

Fig. 130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4116
4200
4110
4170
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4612
4114
4112
4150
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4172
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4654
4610
4662
4614
4652
4660
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4194
4190
4198
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4154a
4194
4192
4334
4350
4360
4304
4306
4300
4330
4328
4500
4506
4502
4506
4508
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4447
4444
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4404
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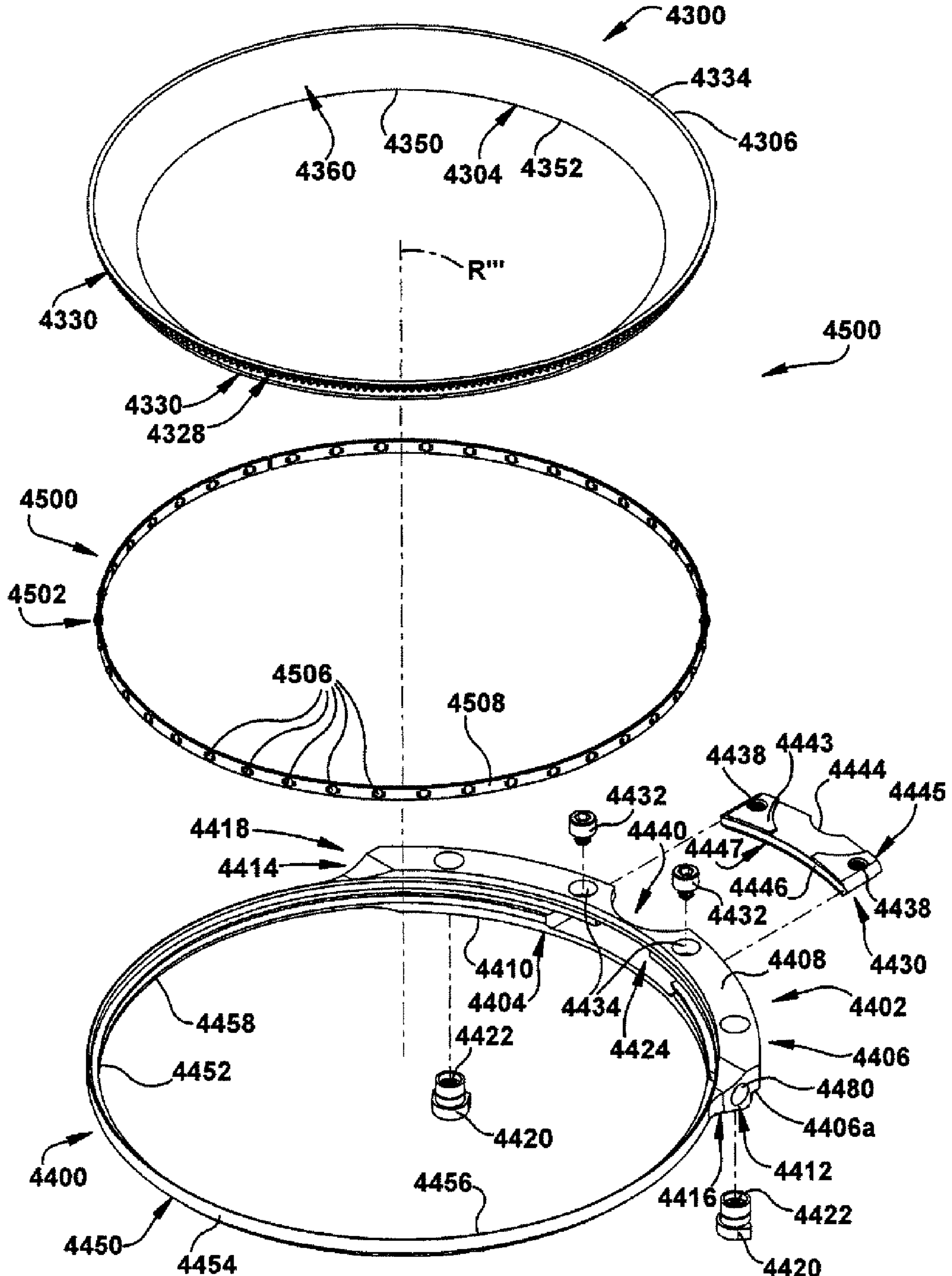
4450
4420

Fig. 131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4352
R'''
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4328
4500
4502
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4445
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4440
4447
4418
4414
4446
4438
4432
4410
4430
4408
4404
4434
4402
4458
4424
4406
4422
4452
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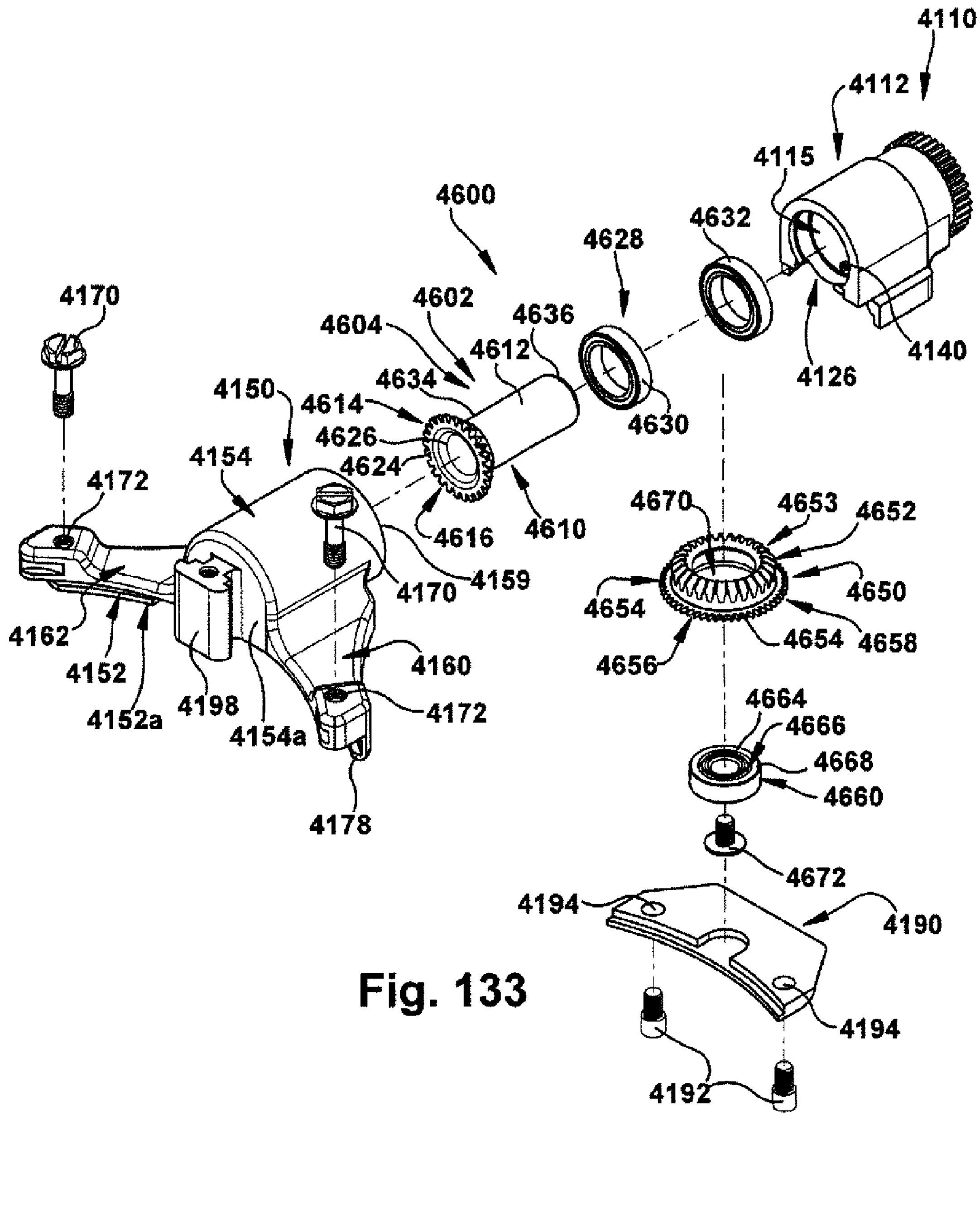
4406a
4420
4412
4400
4416
4422
4456
4450
4454
4420

Fig. 132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4162
4152
4152a
4198
4154a
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4172
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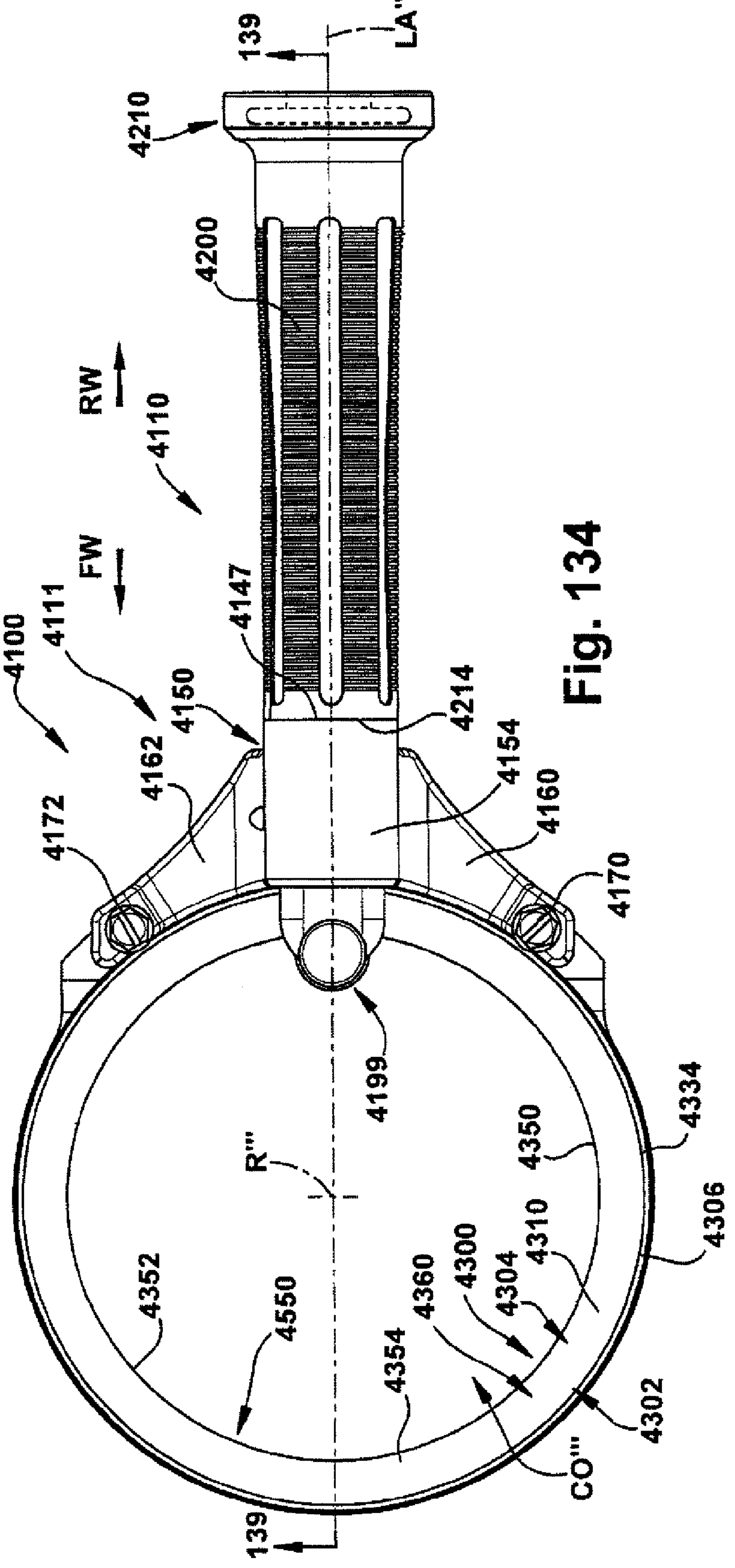
4666
4668
4660
4672
4194
4190
4194
4192

Fig. 133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LA''
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FW
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4111
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4150
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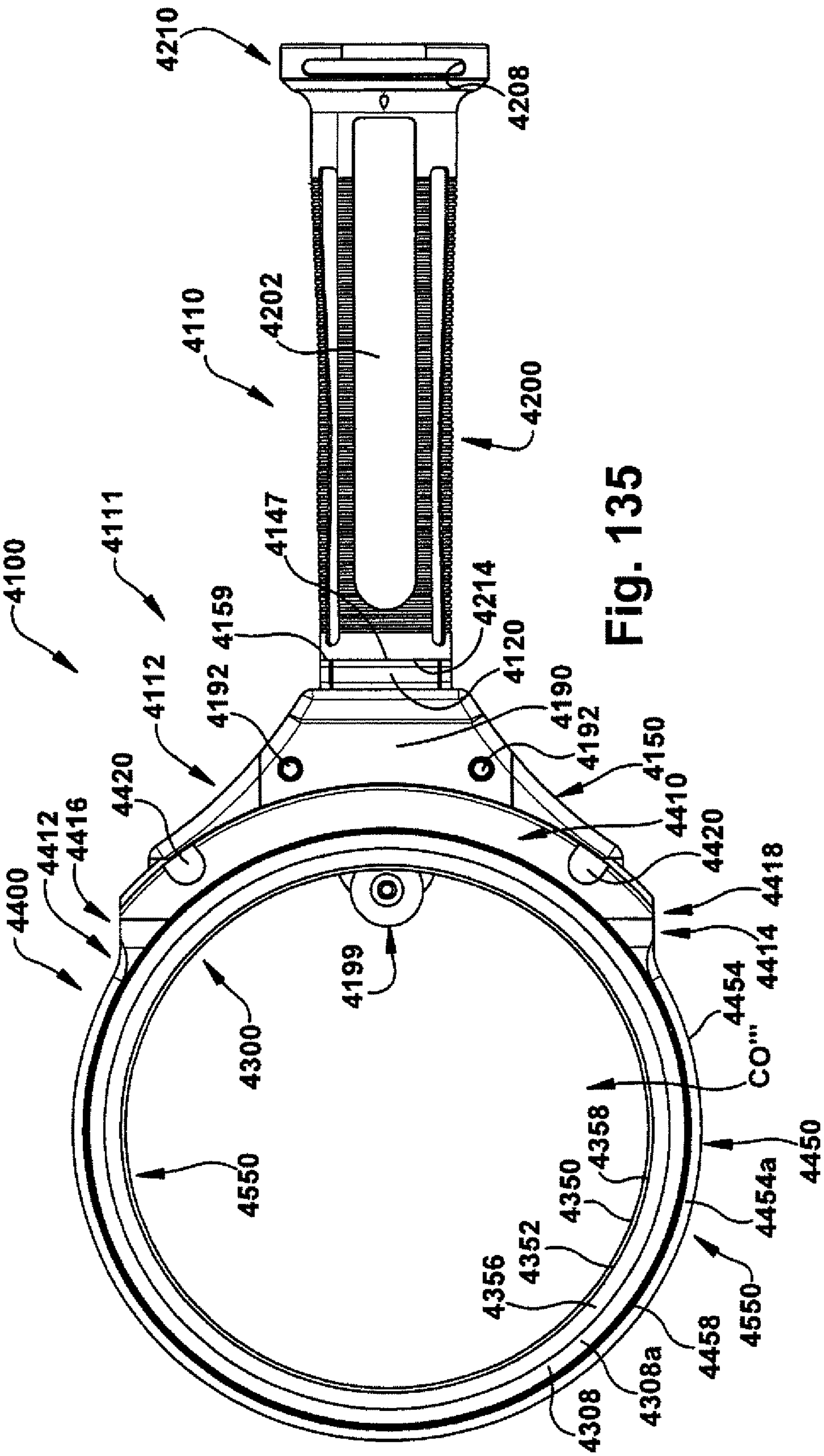
4162
4154
4172
4160
4170
4199
4334
4350
R'''
4306
4310
4300
4304
4360
4352
4550
4354
4302
CO'''
139

Fig. 134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4150
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4420
4412
4416
4418
4400
4414
4199
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CO'''
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4454a
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4550
4458
4308a
4308

Fig. 135

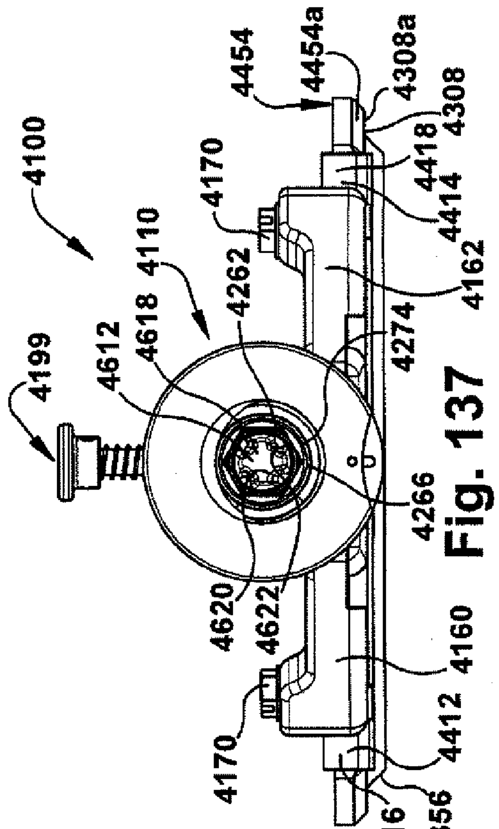


Fig. 137

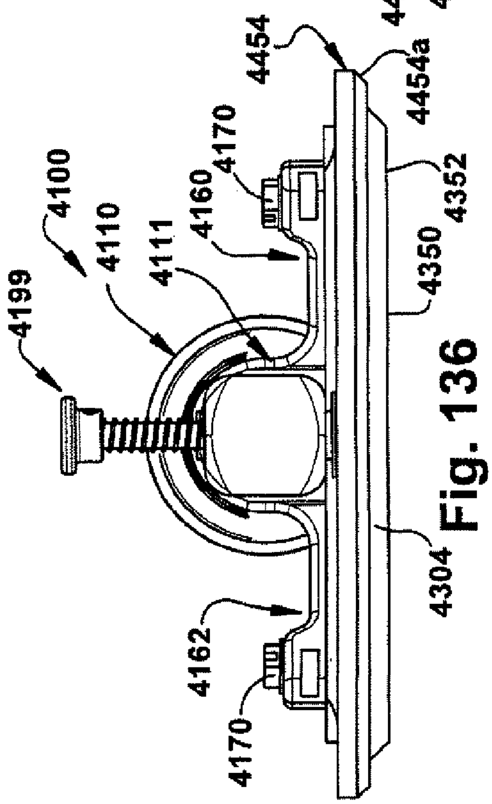


Fig. 136

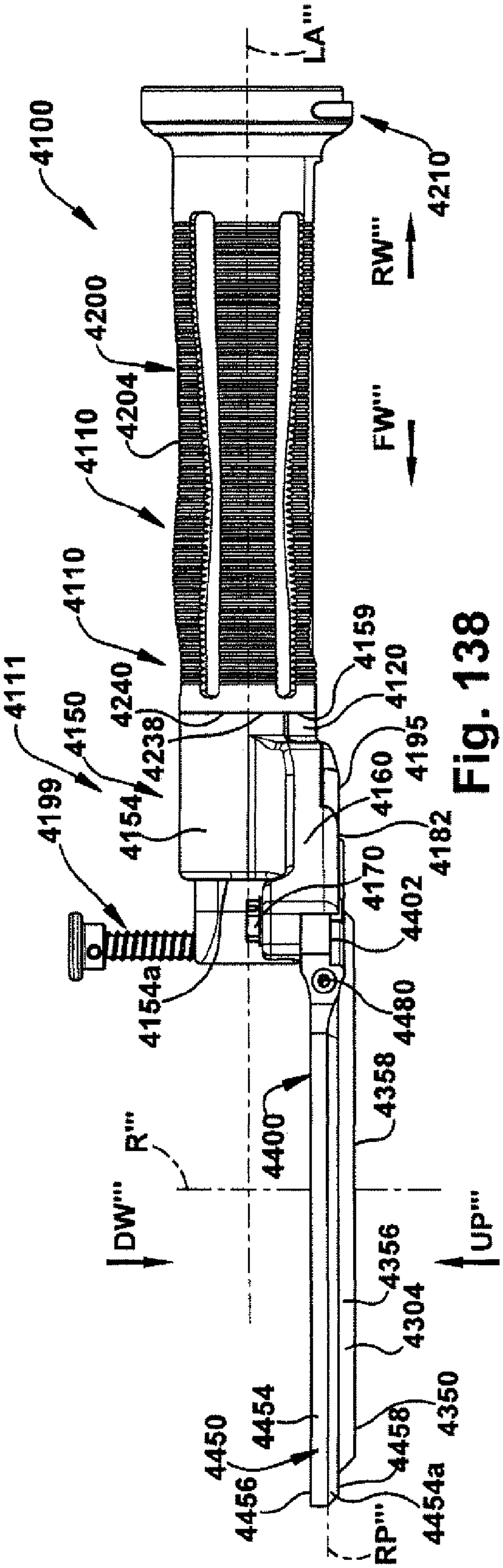
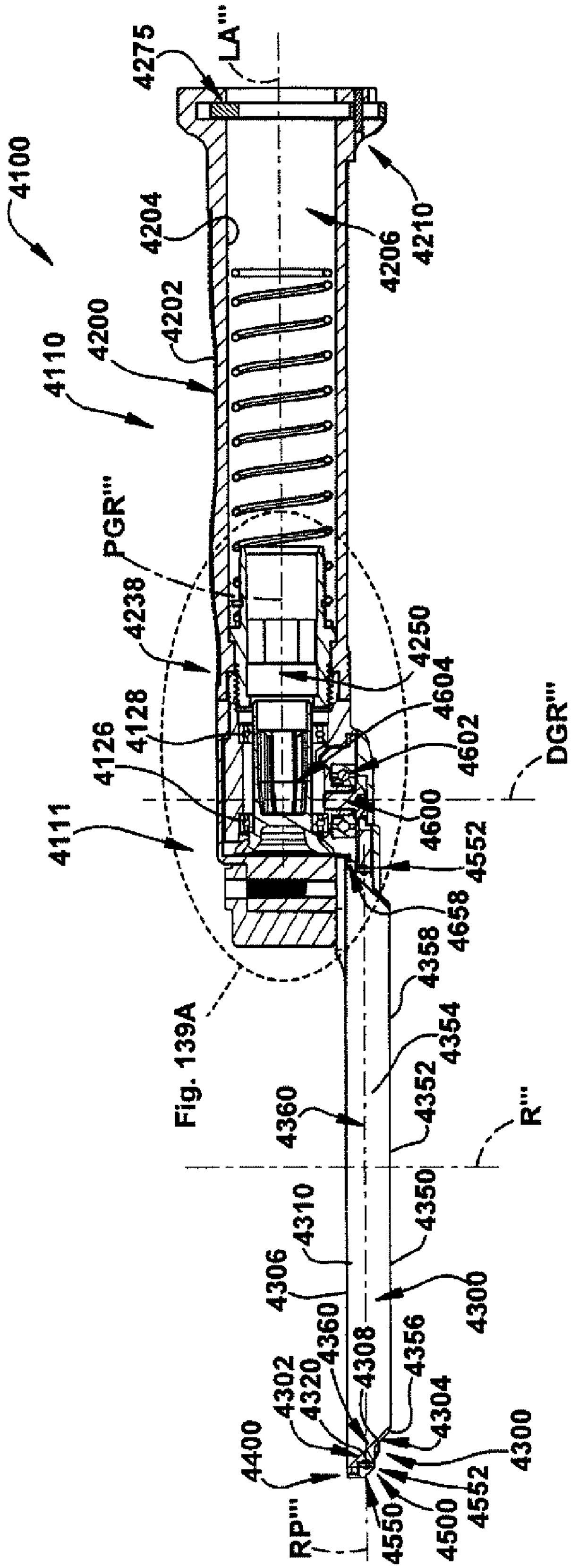


Fig. 138



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4110
PGR'''
4238
4250
4604
DGR'''
4128
4602
4126
4600
4111
4552
4658
4358
Fig. 139A
4354
4352
4360
R'''
4350
4310
4306
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4308
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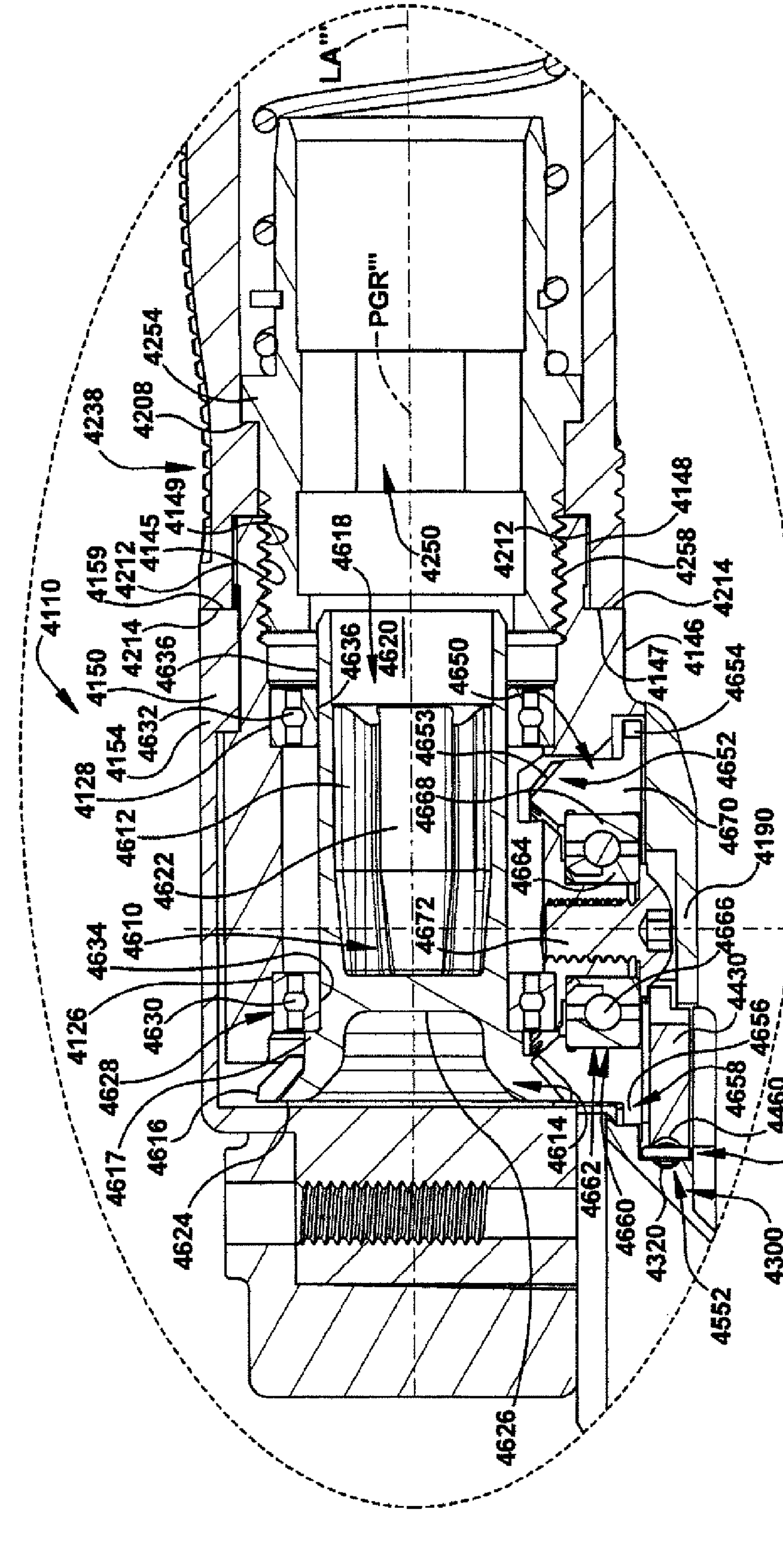
4302
4320
4304
4400
4300
4552
4500
4550
RP'''

Fig. 139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DGR'''
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4610
4634
4126
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4626
4618
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4653
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4614
4662
4660
4320
4552
4300
4504
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4212

Fig. 139A

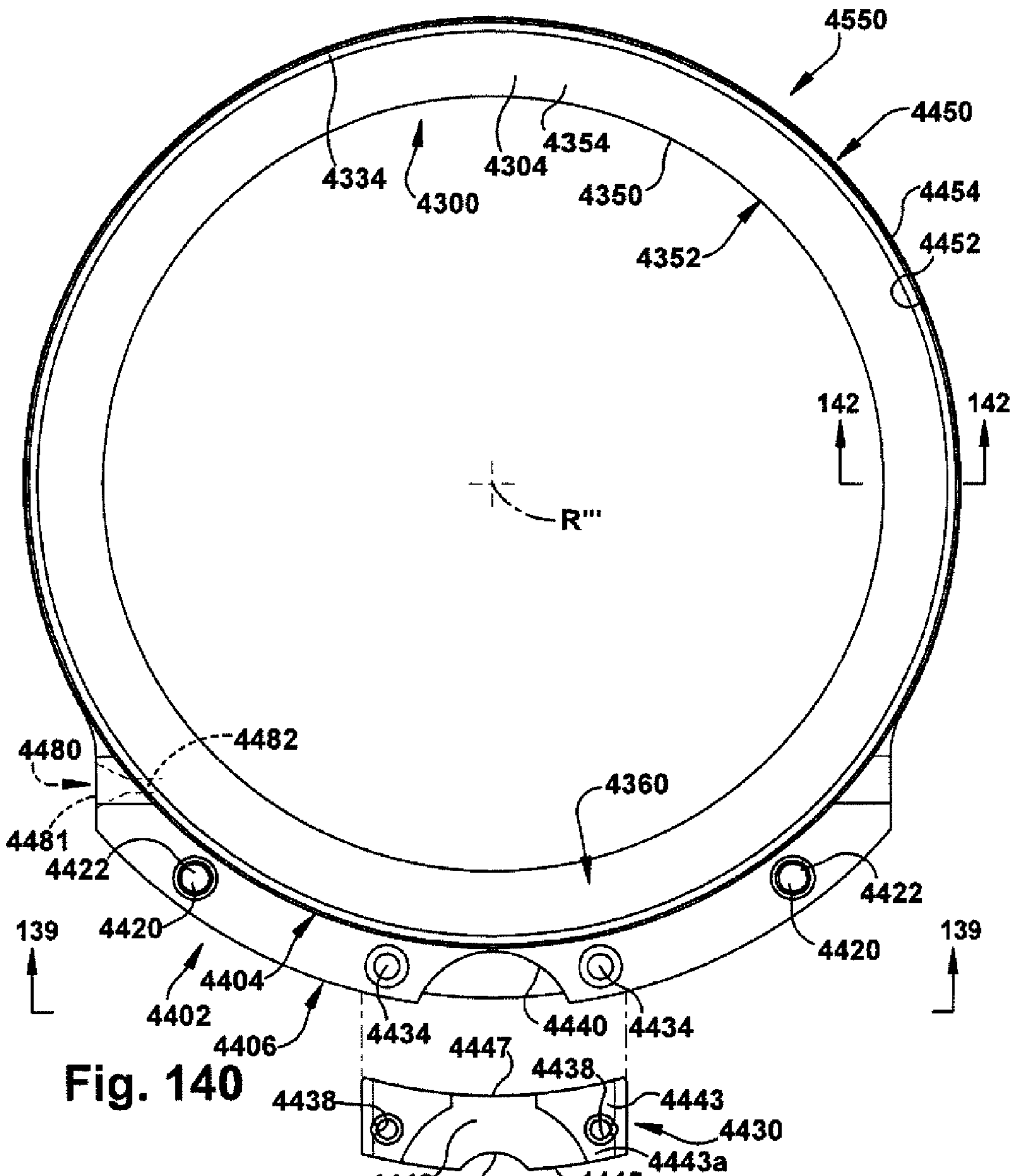


Fig. 140

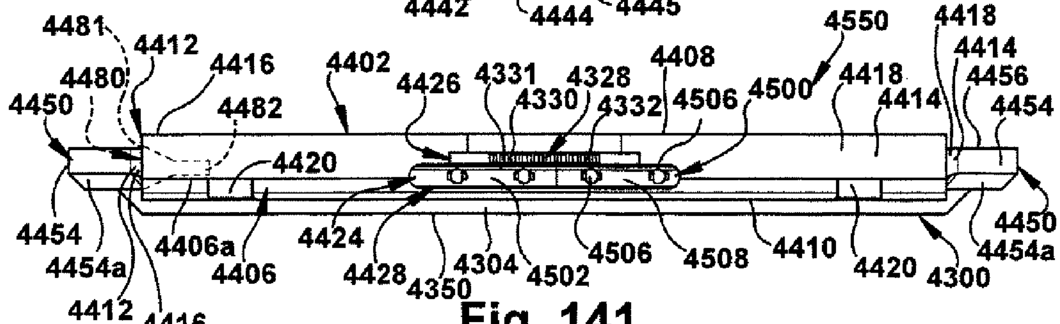
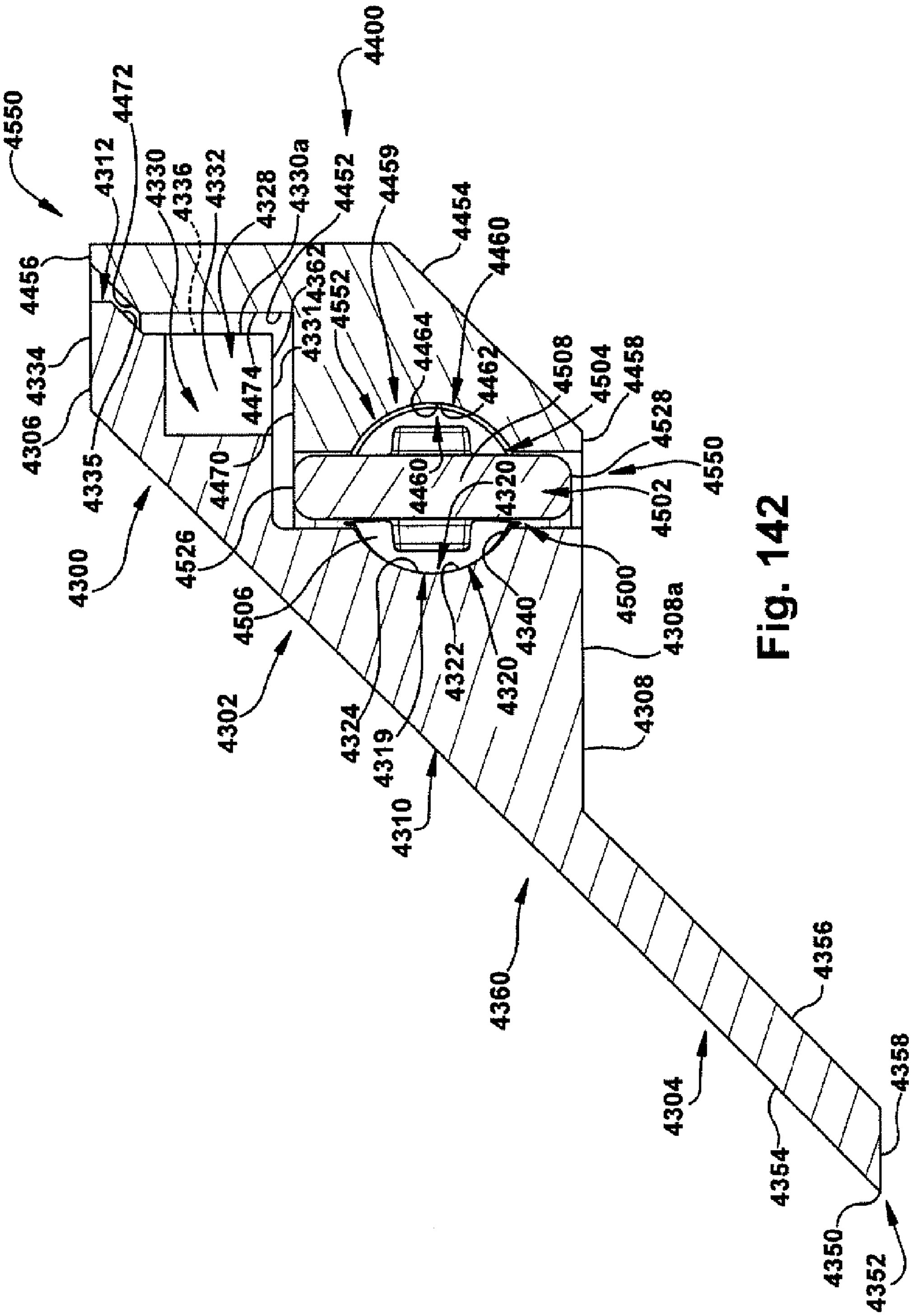


Fig. 141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4331
4464
4462
4334
4474
4508
4504
4458
4306
4335
4470
4460
4320
4528
4550
4502
4300
4526
4506
4500
4340
4308a
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4350
4352

Fig. 142

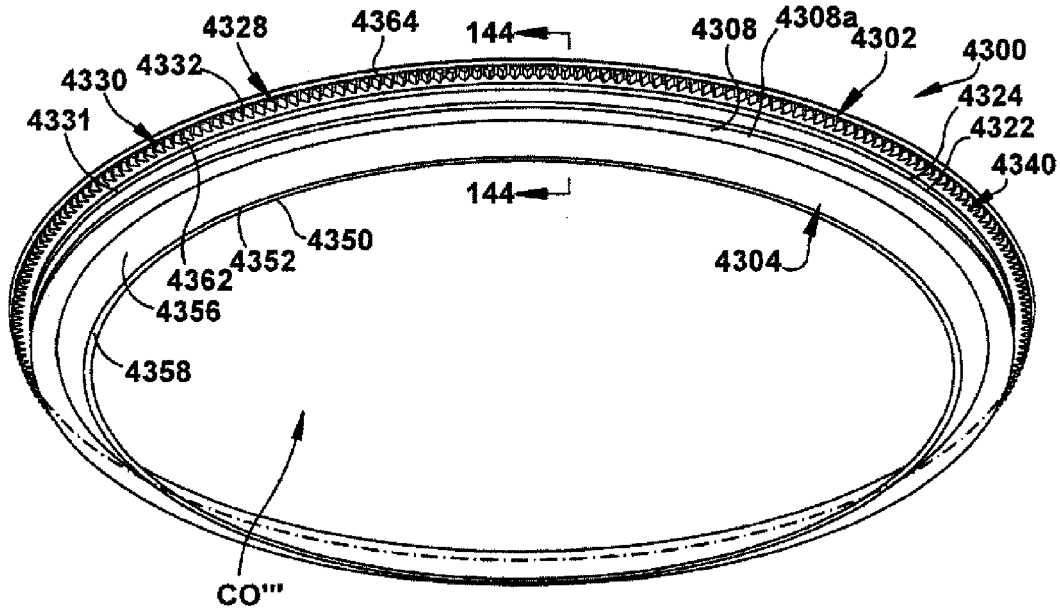


Fig. 143

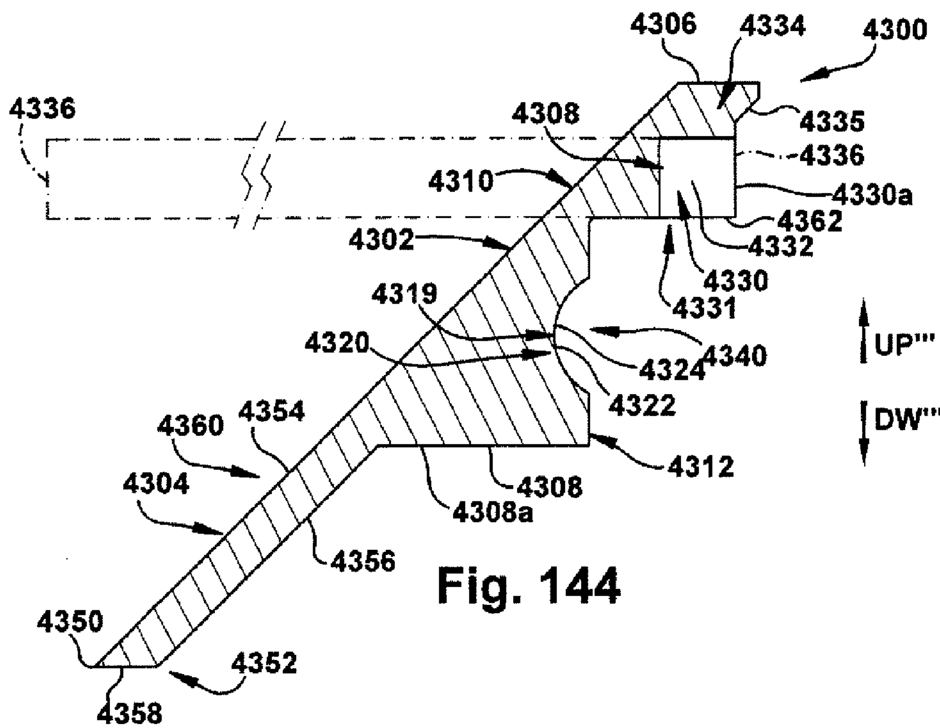


Fig. 144

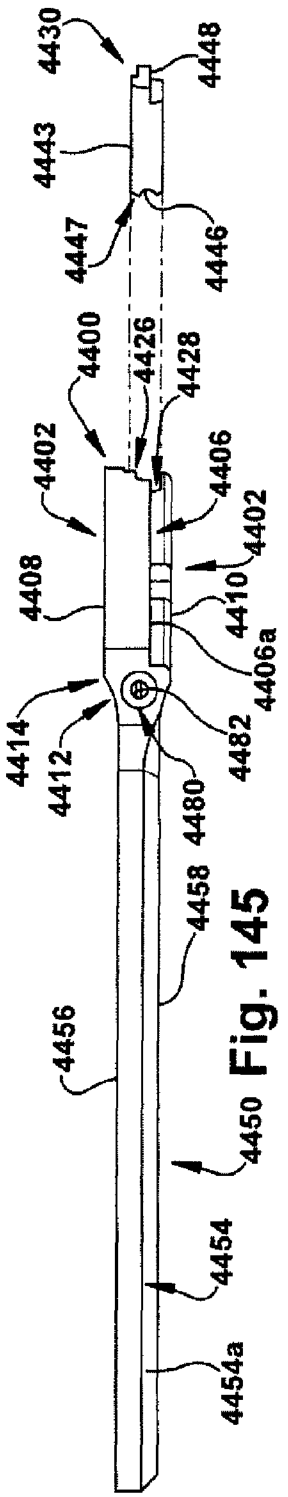


Fig. 145

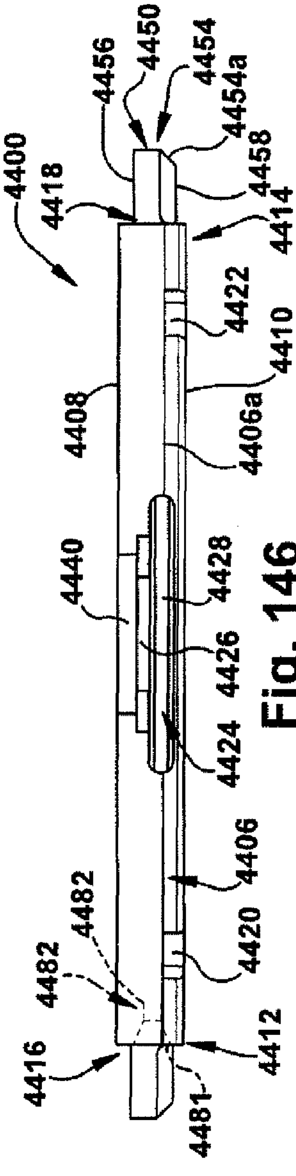


Fig. 146

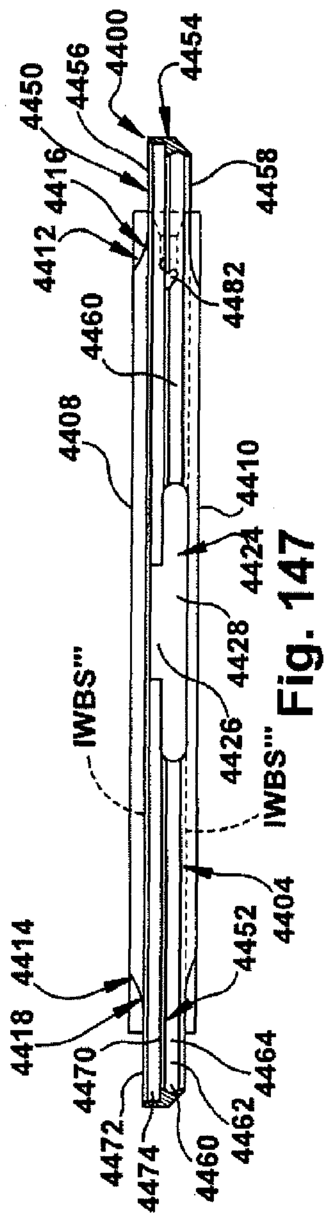
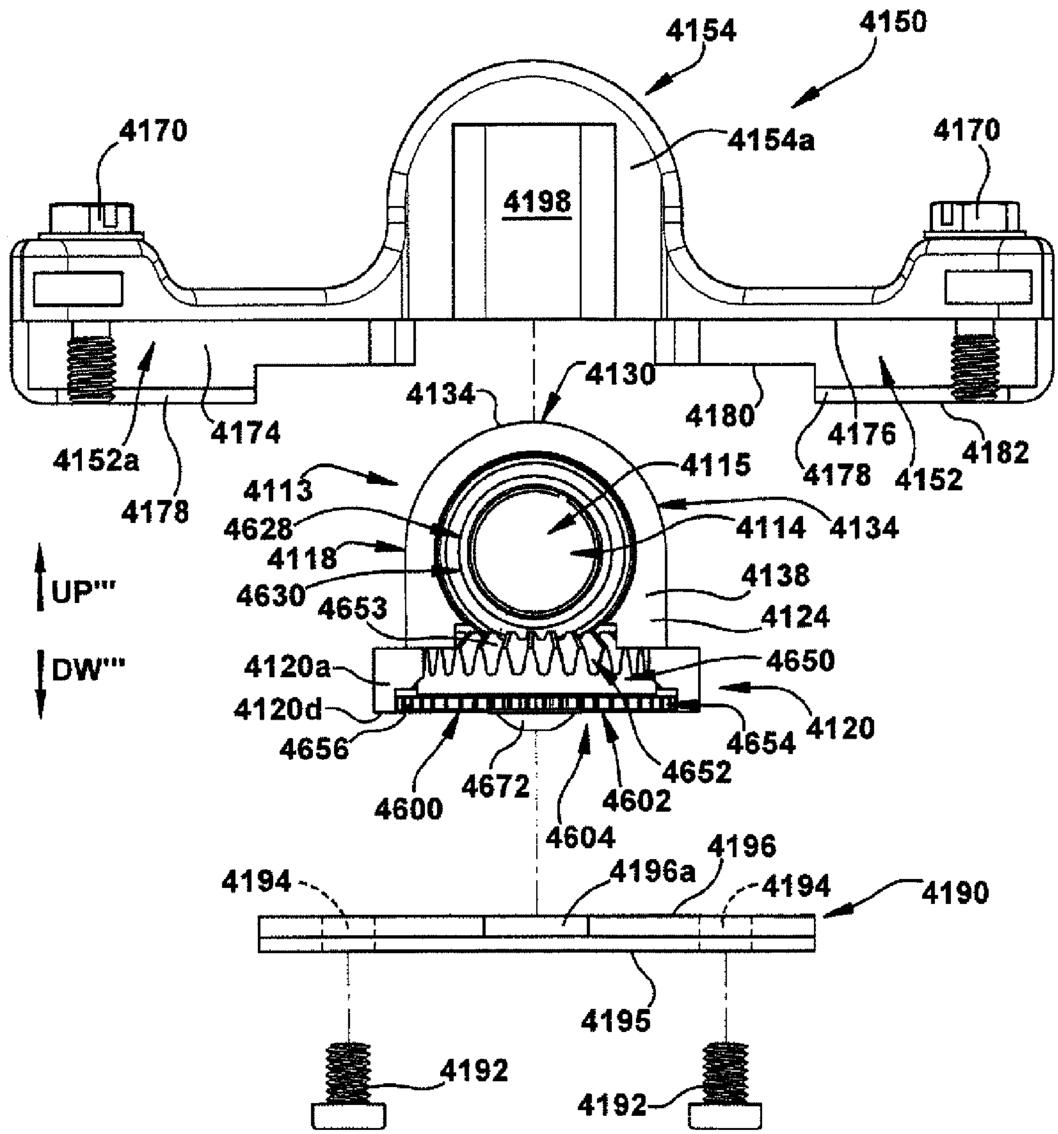


Fig. 147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4178
4152
4178
4113
4115
4628
4114
4134
4118
4138
UP'''
4630
4653
4124
DW'''
4120a
4650
4120d
4120
4656
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4196a
4194
4190
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4192

Fig. 148

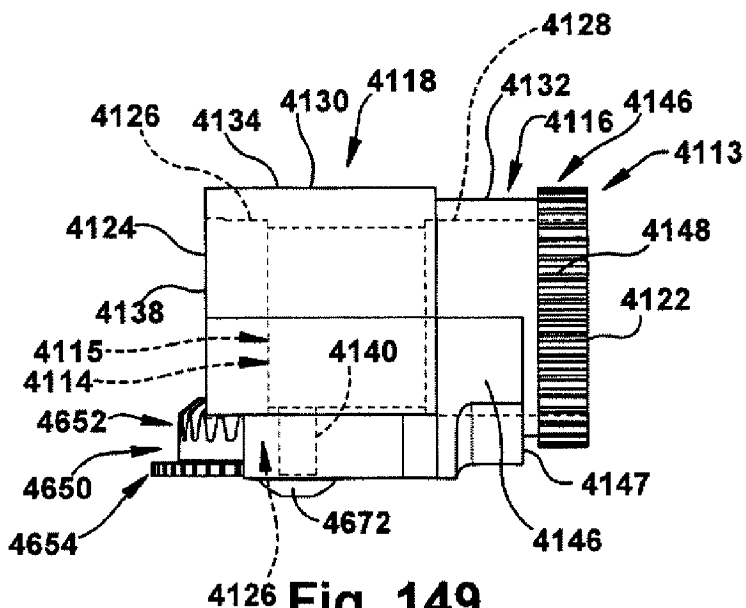


Fig. 149

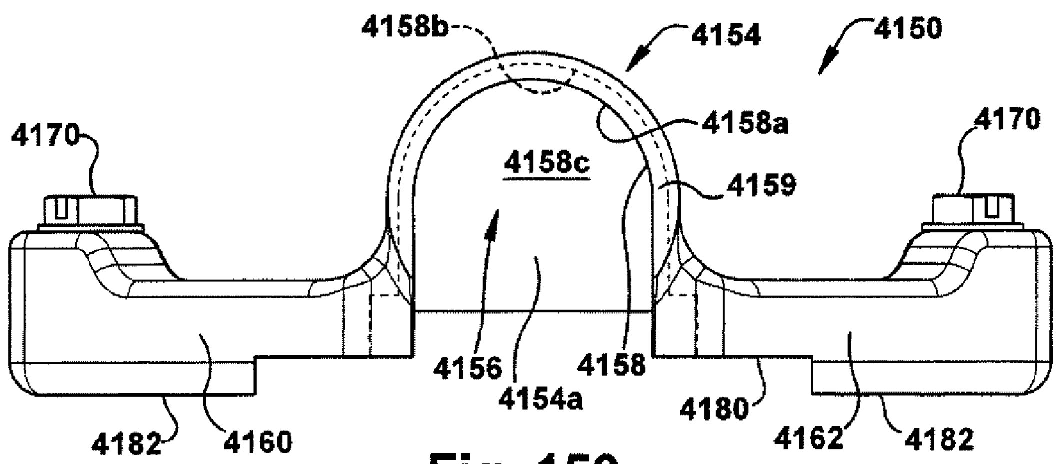


Fig. 150

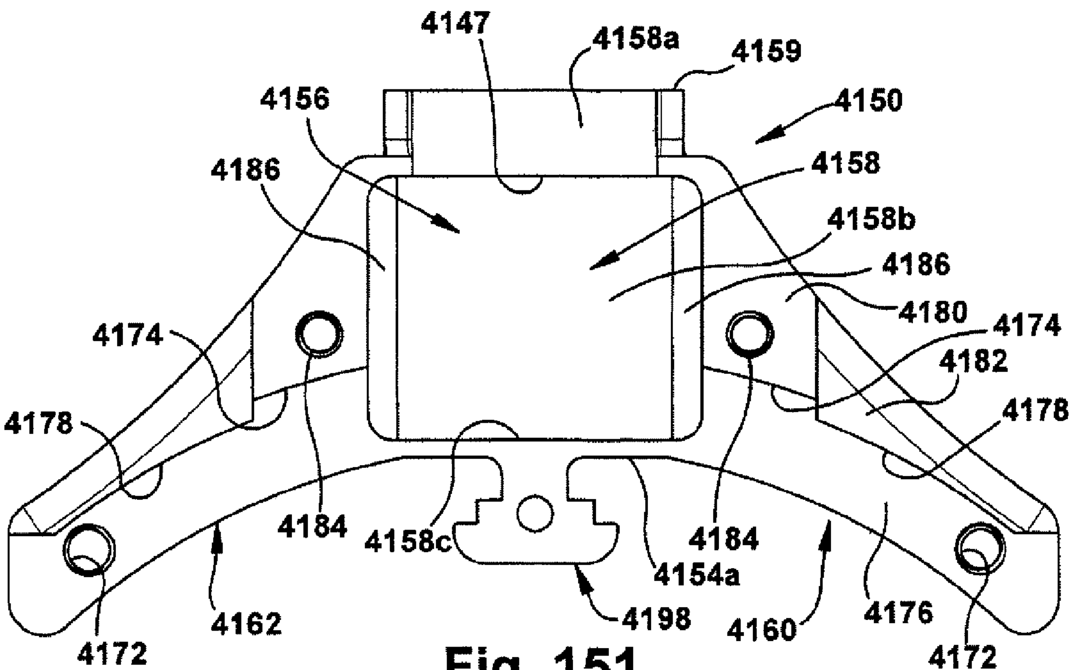


Fig. 151

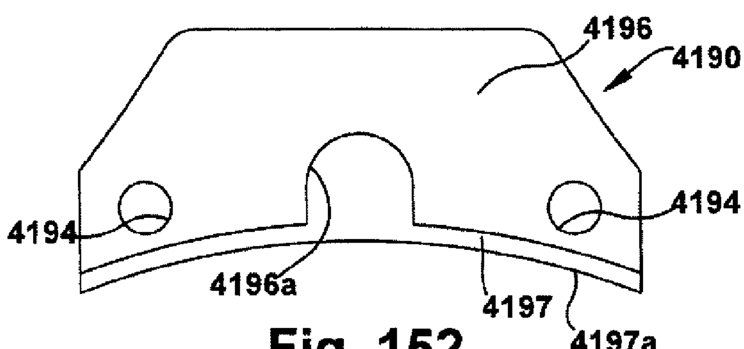


Fig. 152

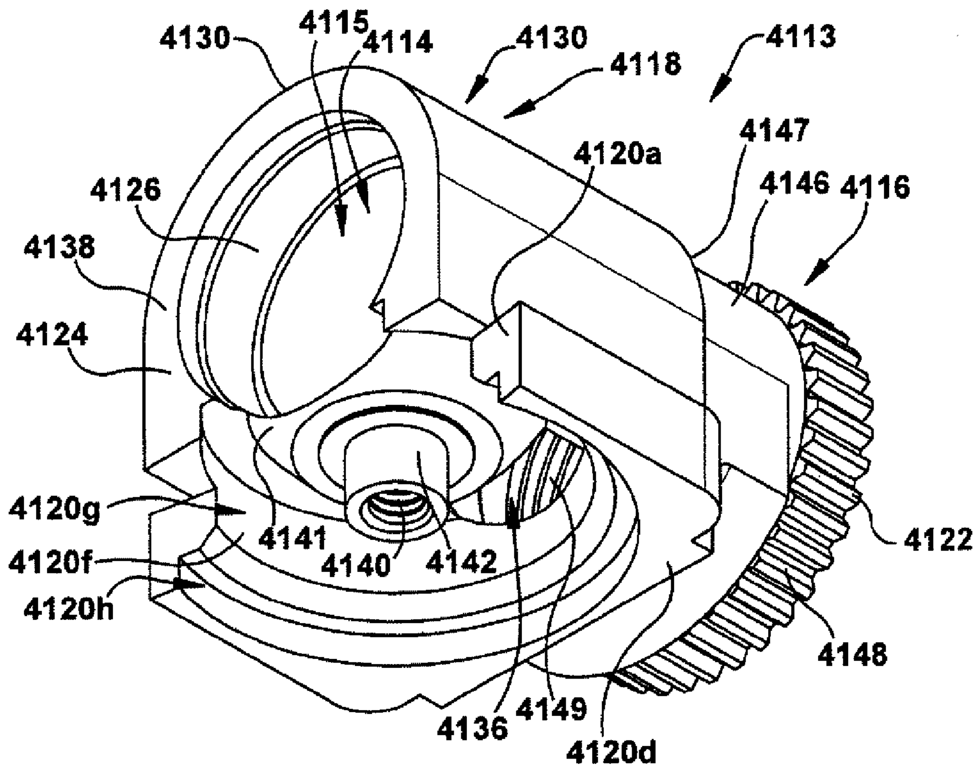
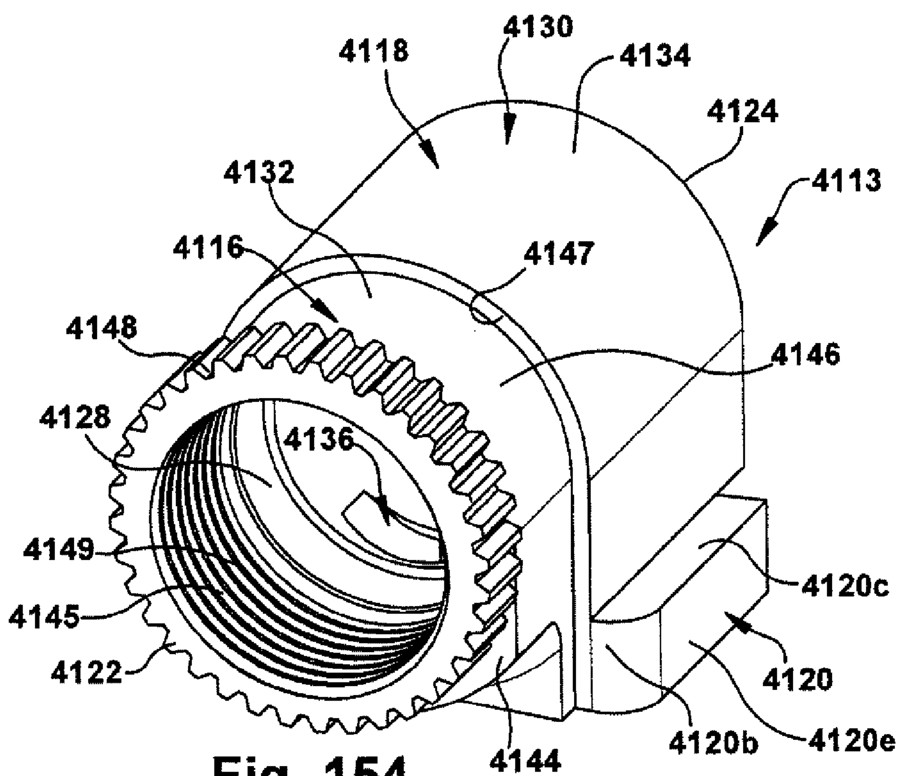


Fig. 153



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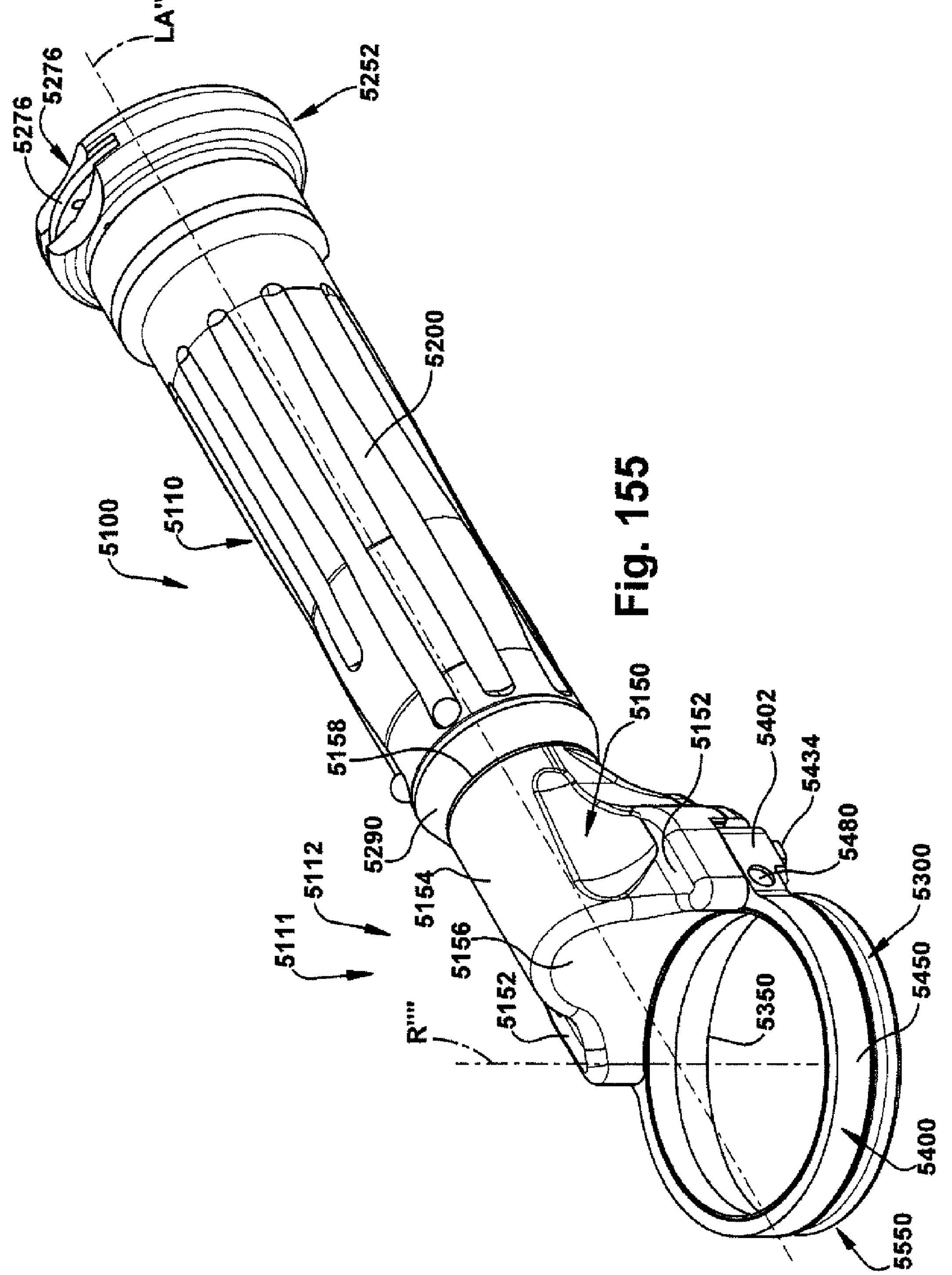
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Fig. 155

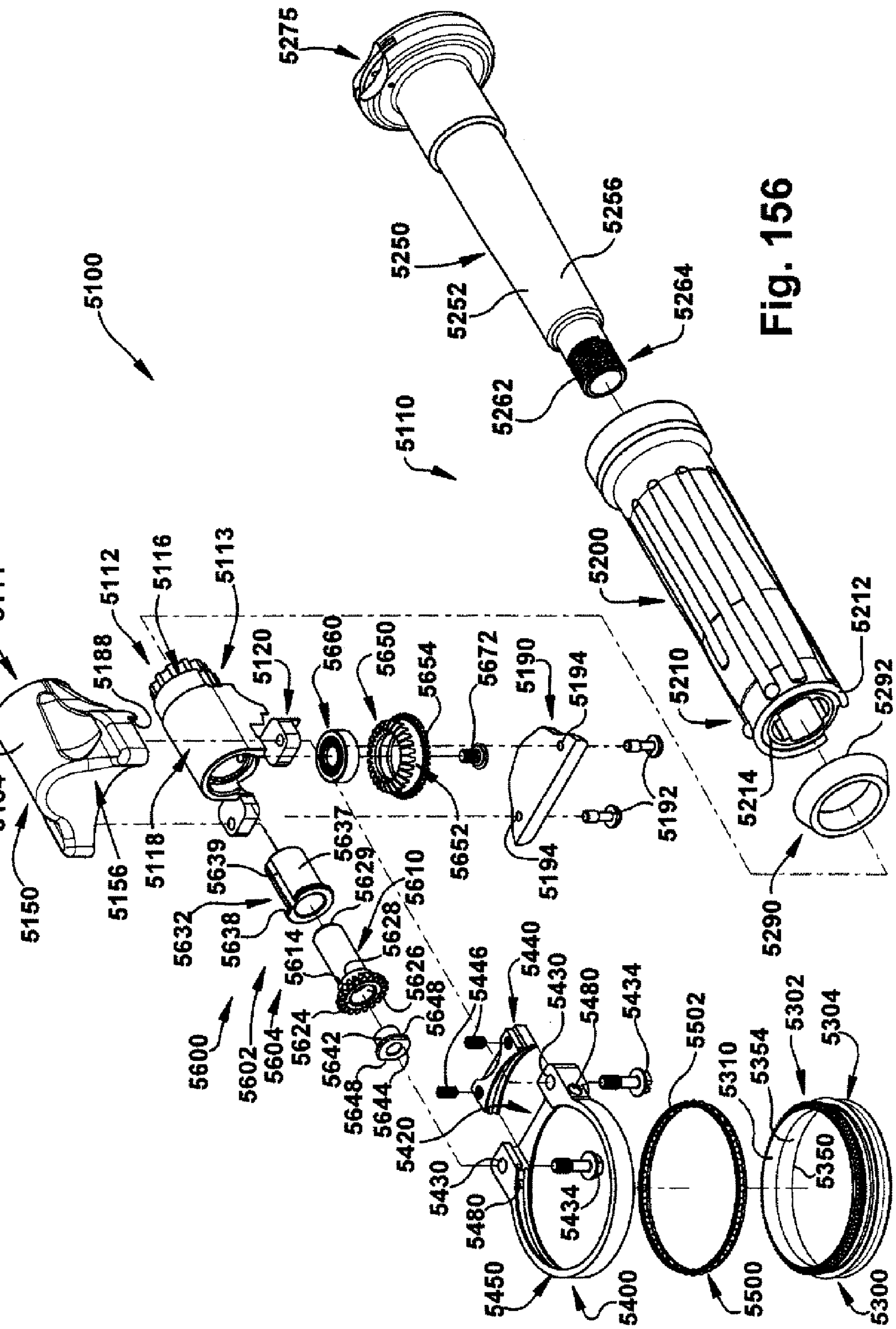
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Fig. 156

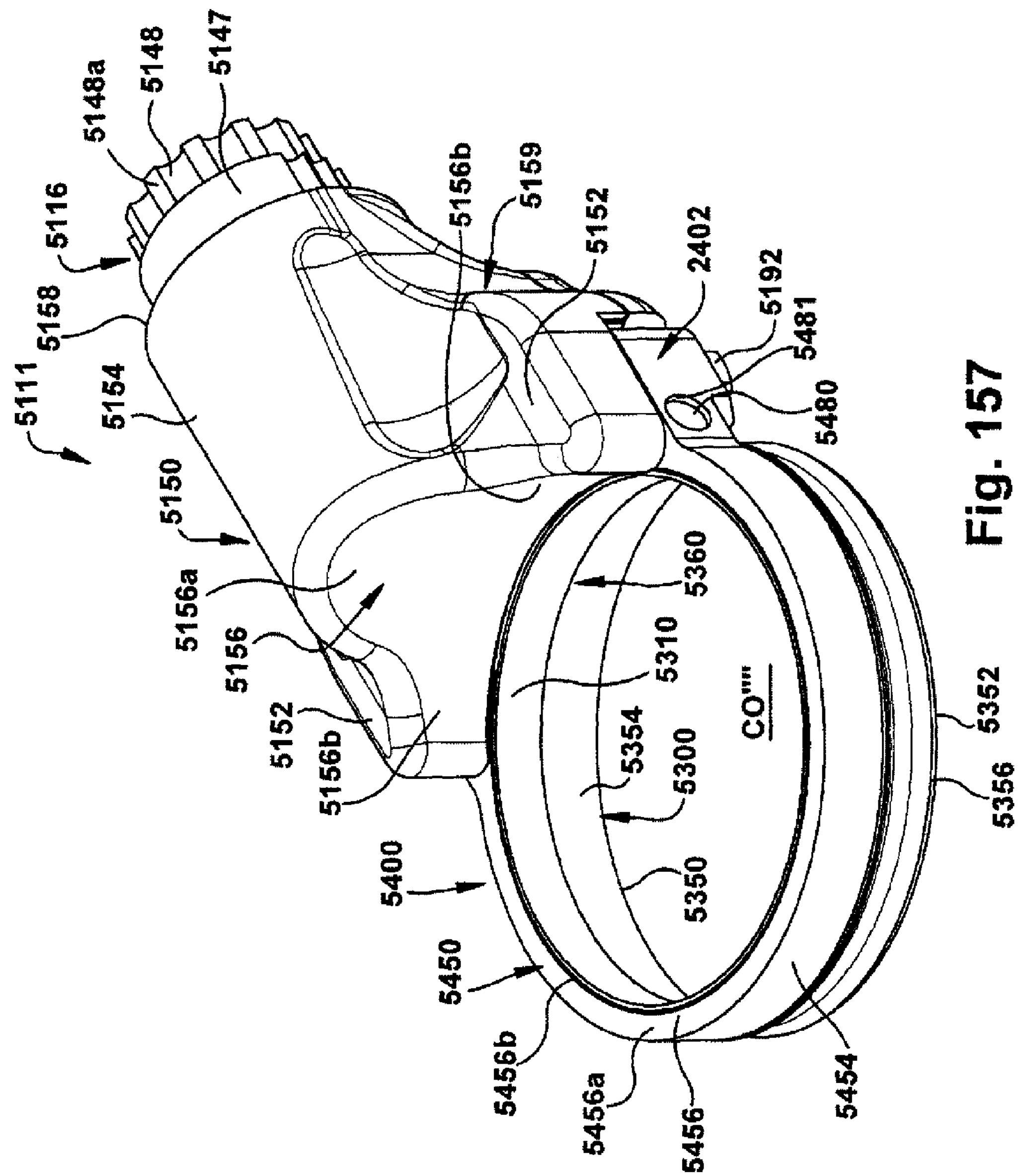
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Fig. 157

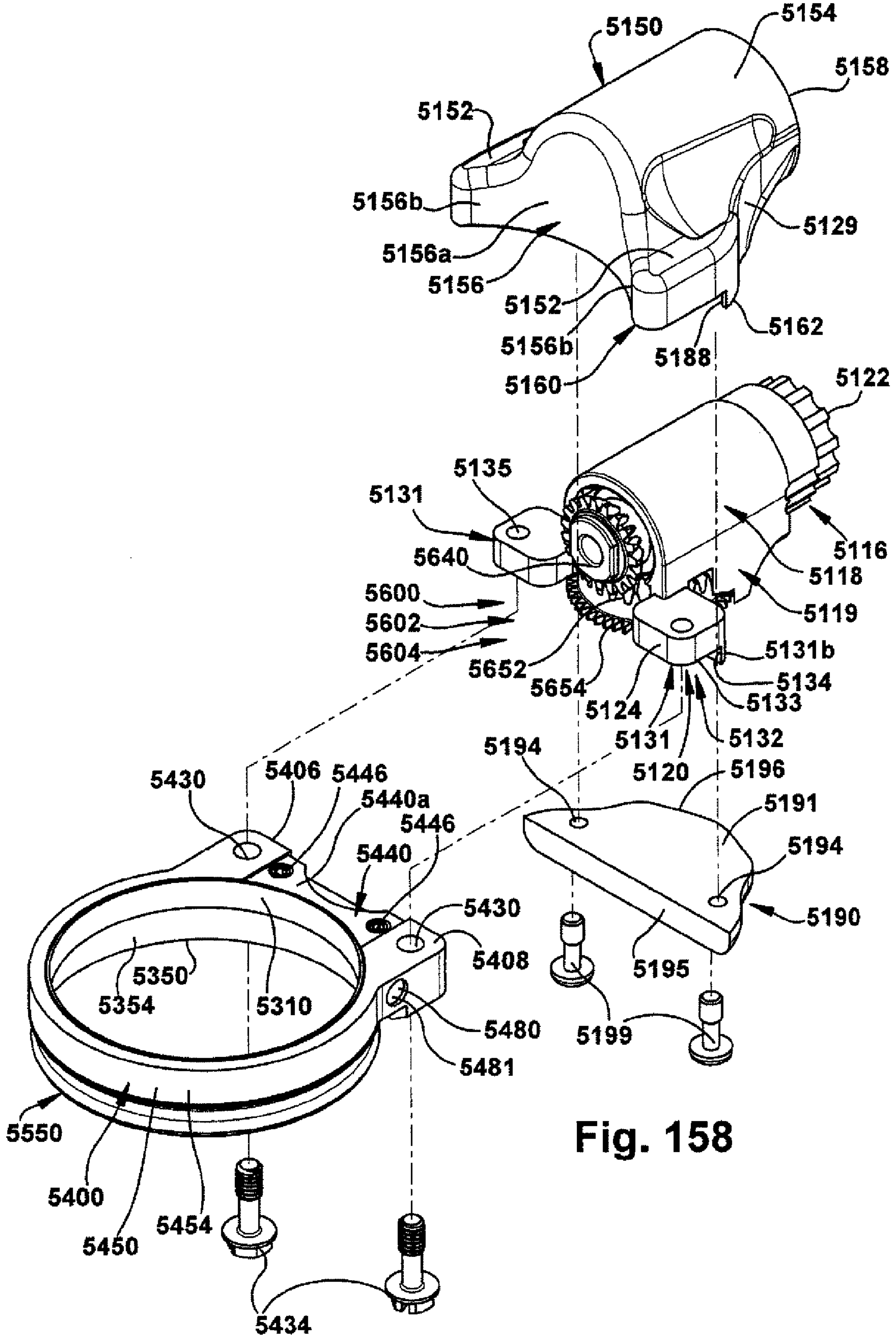
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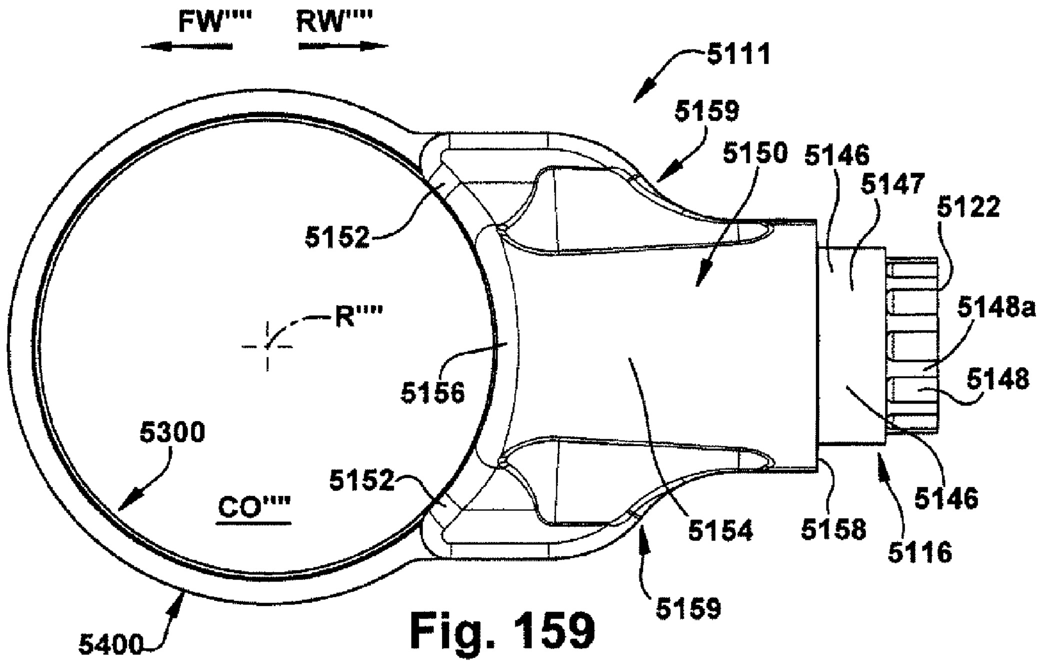
Fig. 158



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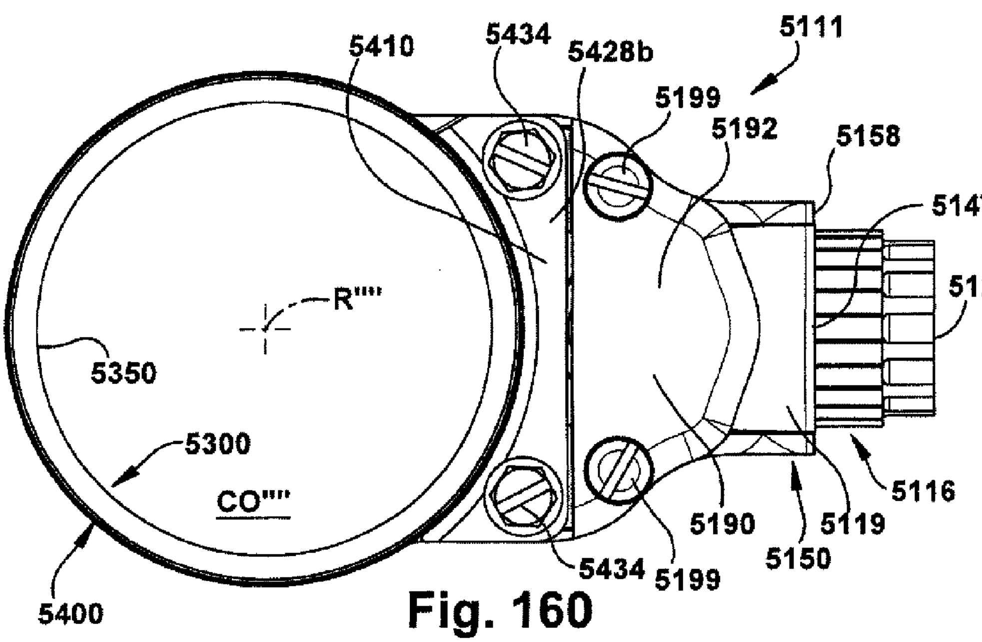

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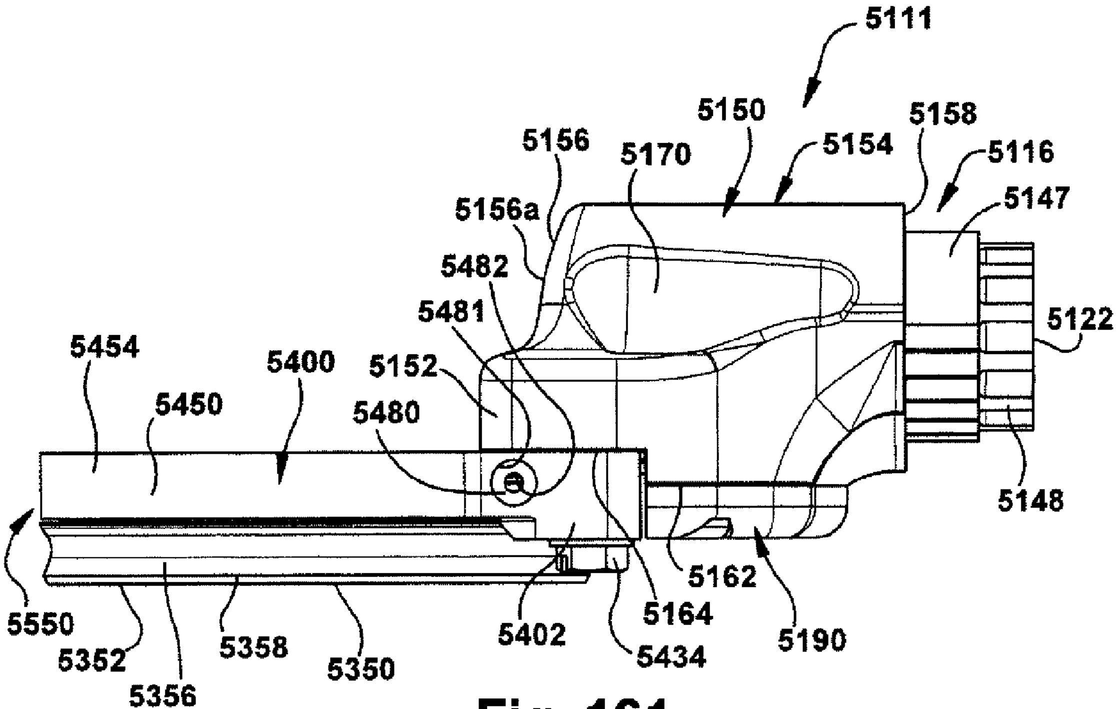
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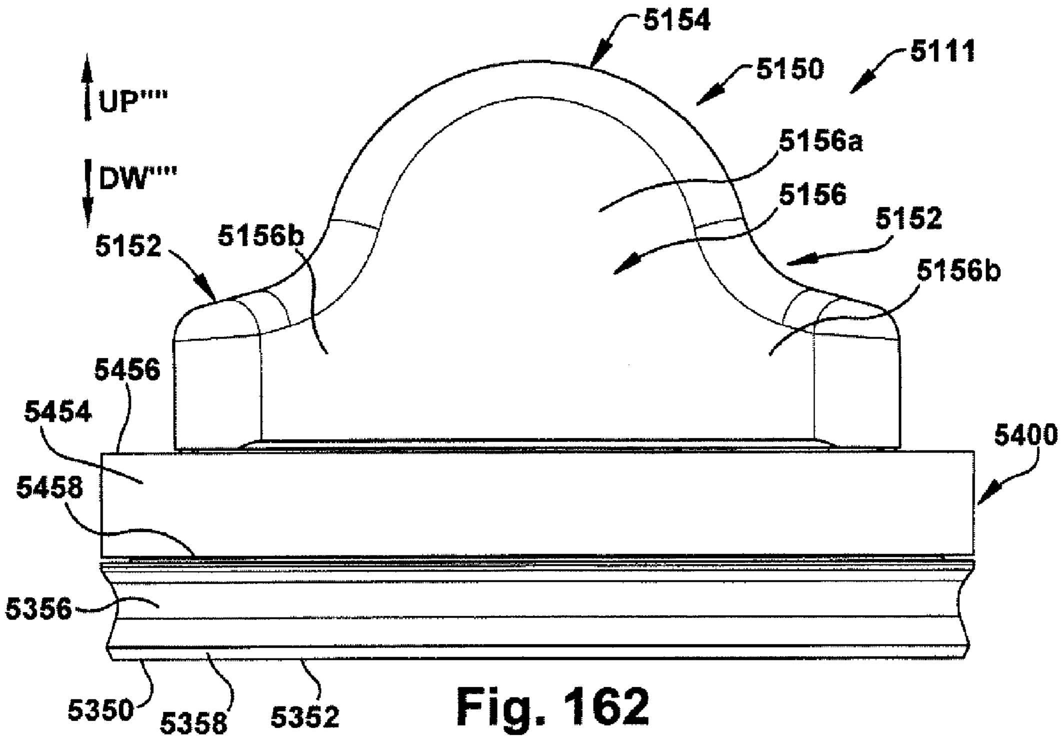
Fig. 161



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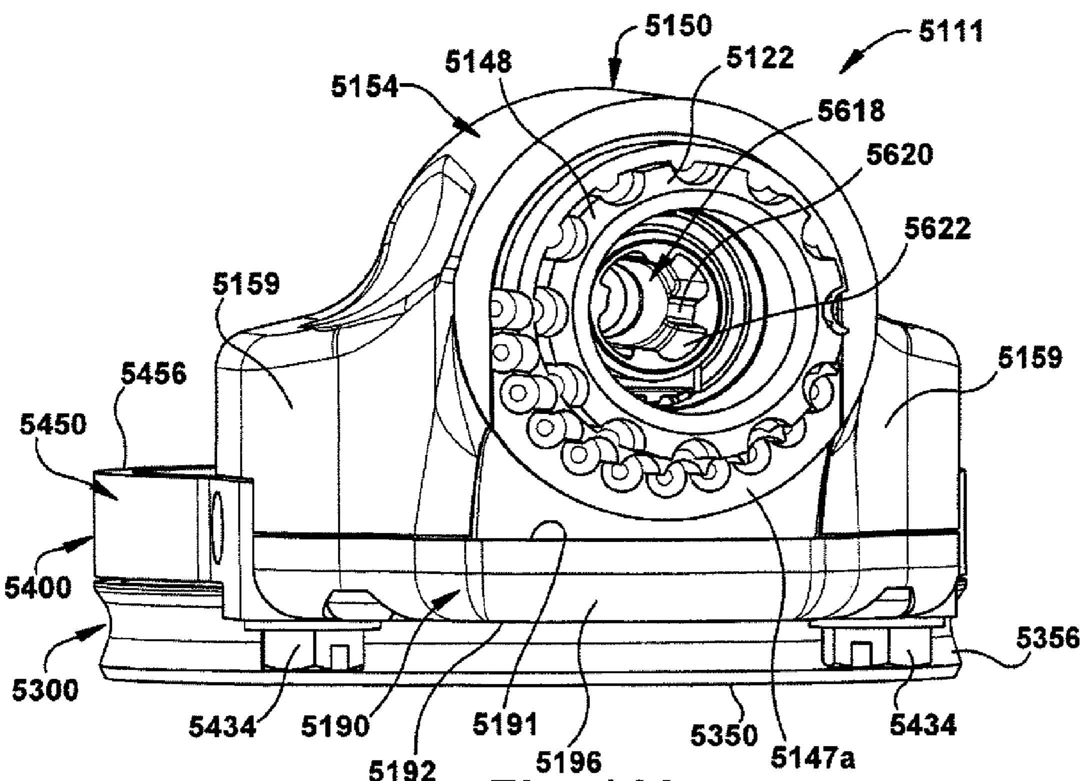

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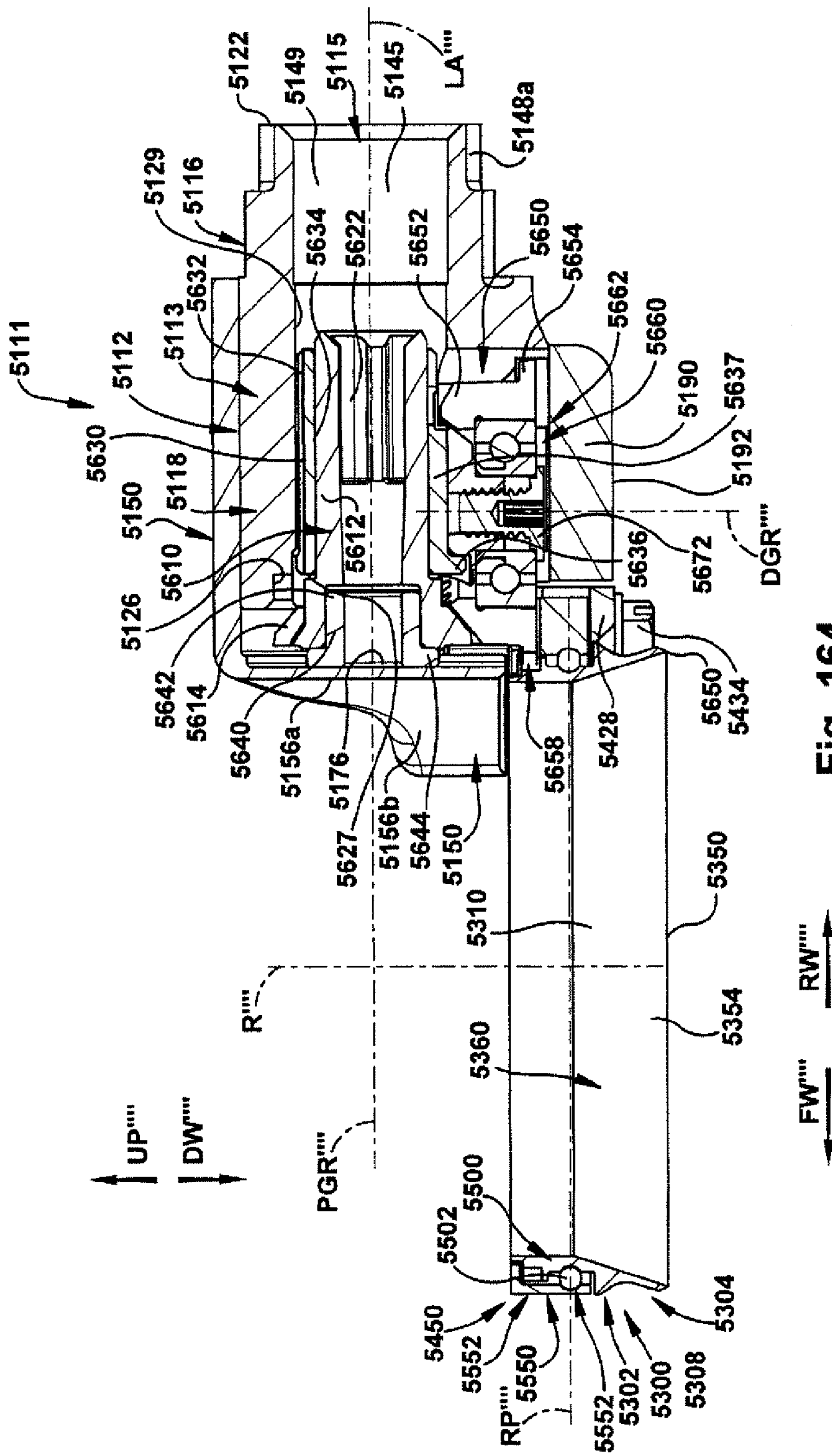
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Fig. 164

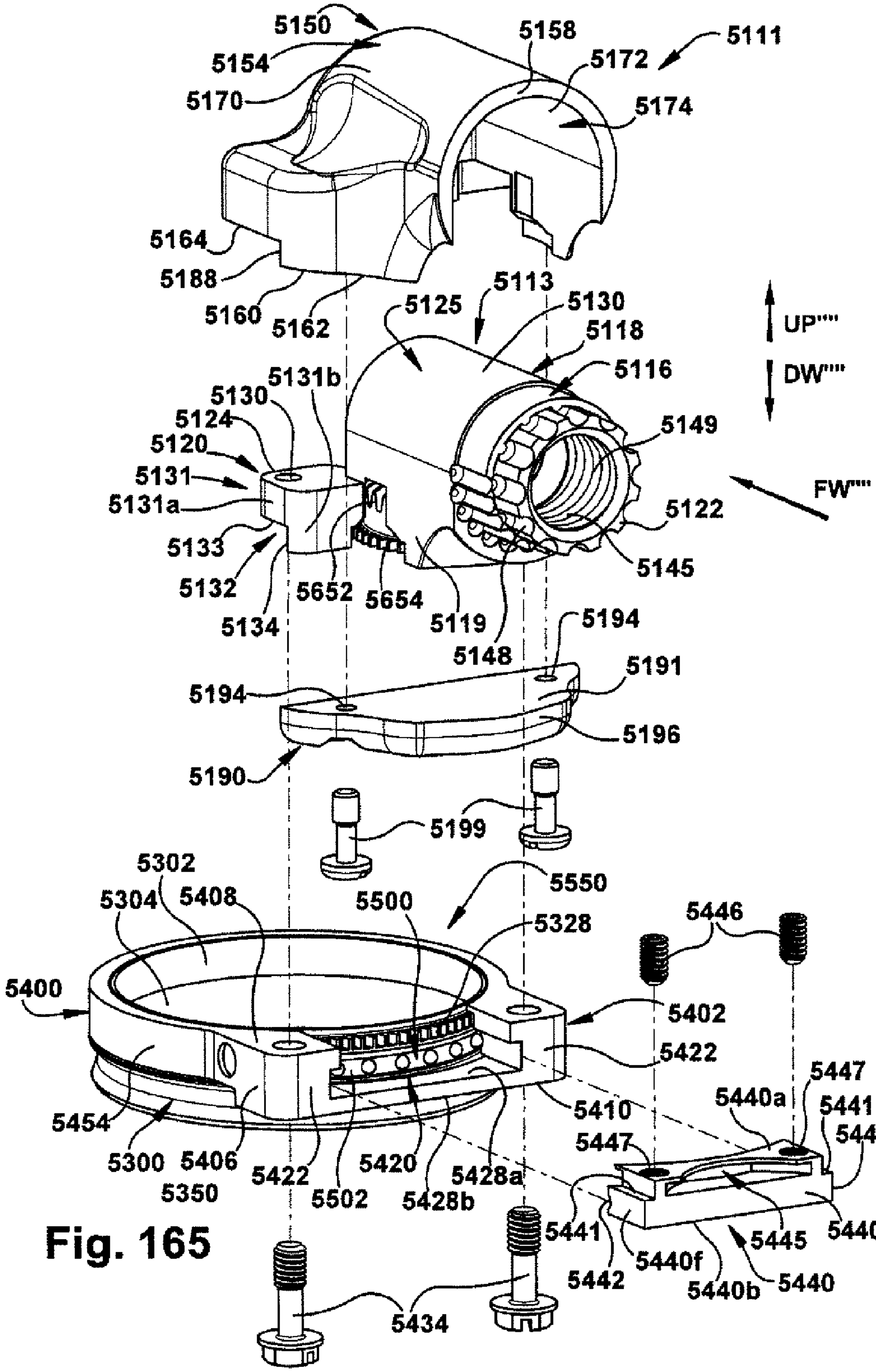
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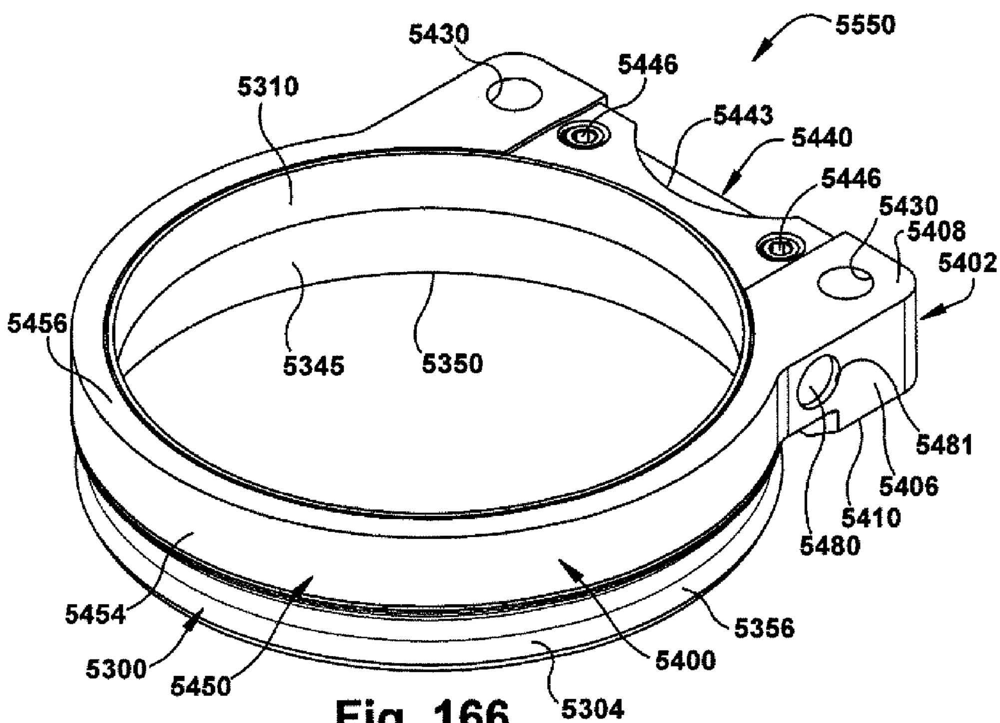
Fig. 165



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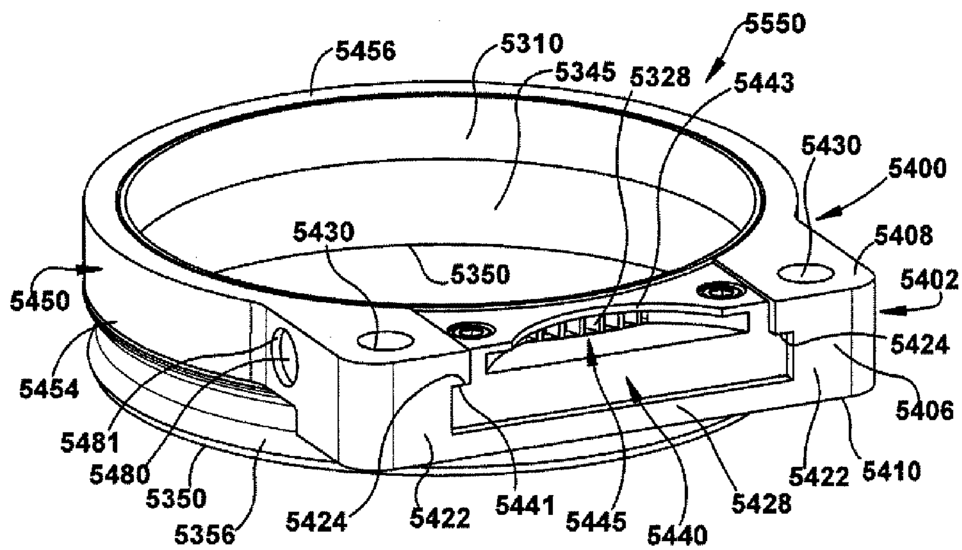

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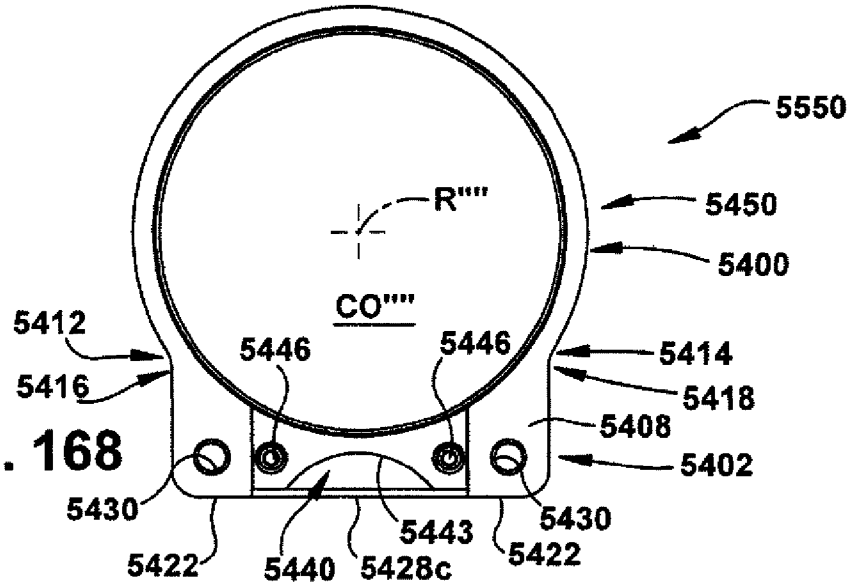

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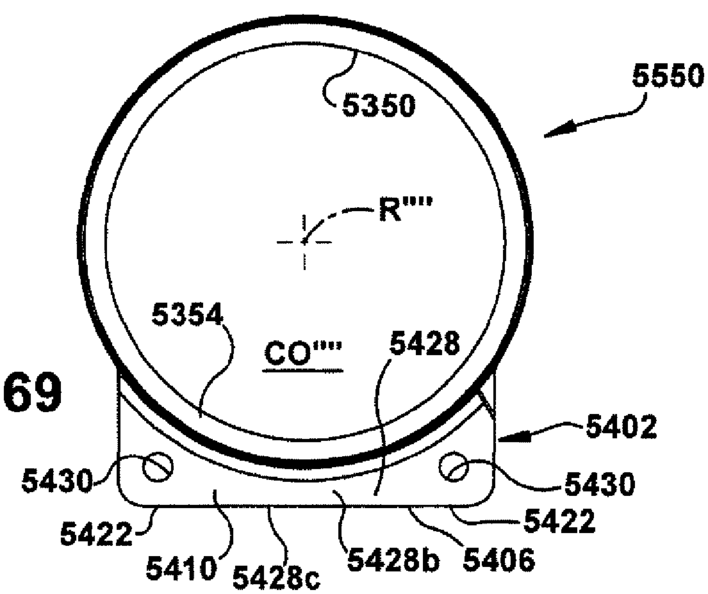

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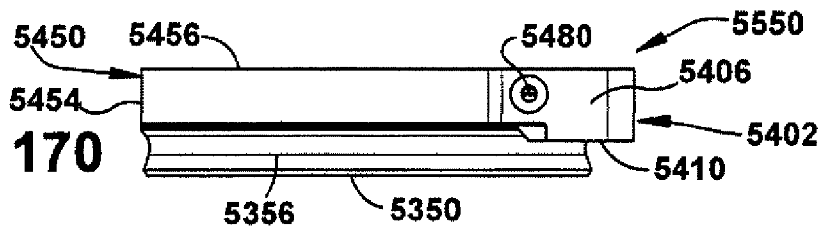

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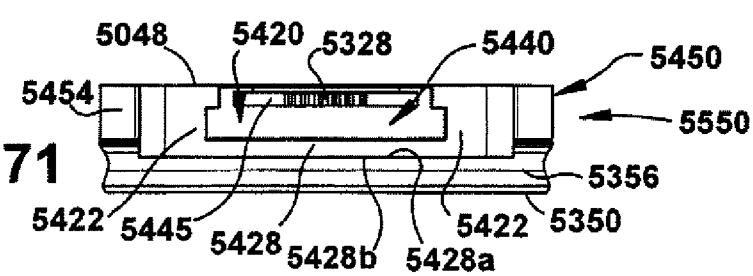

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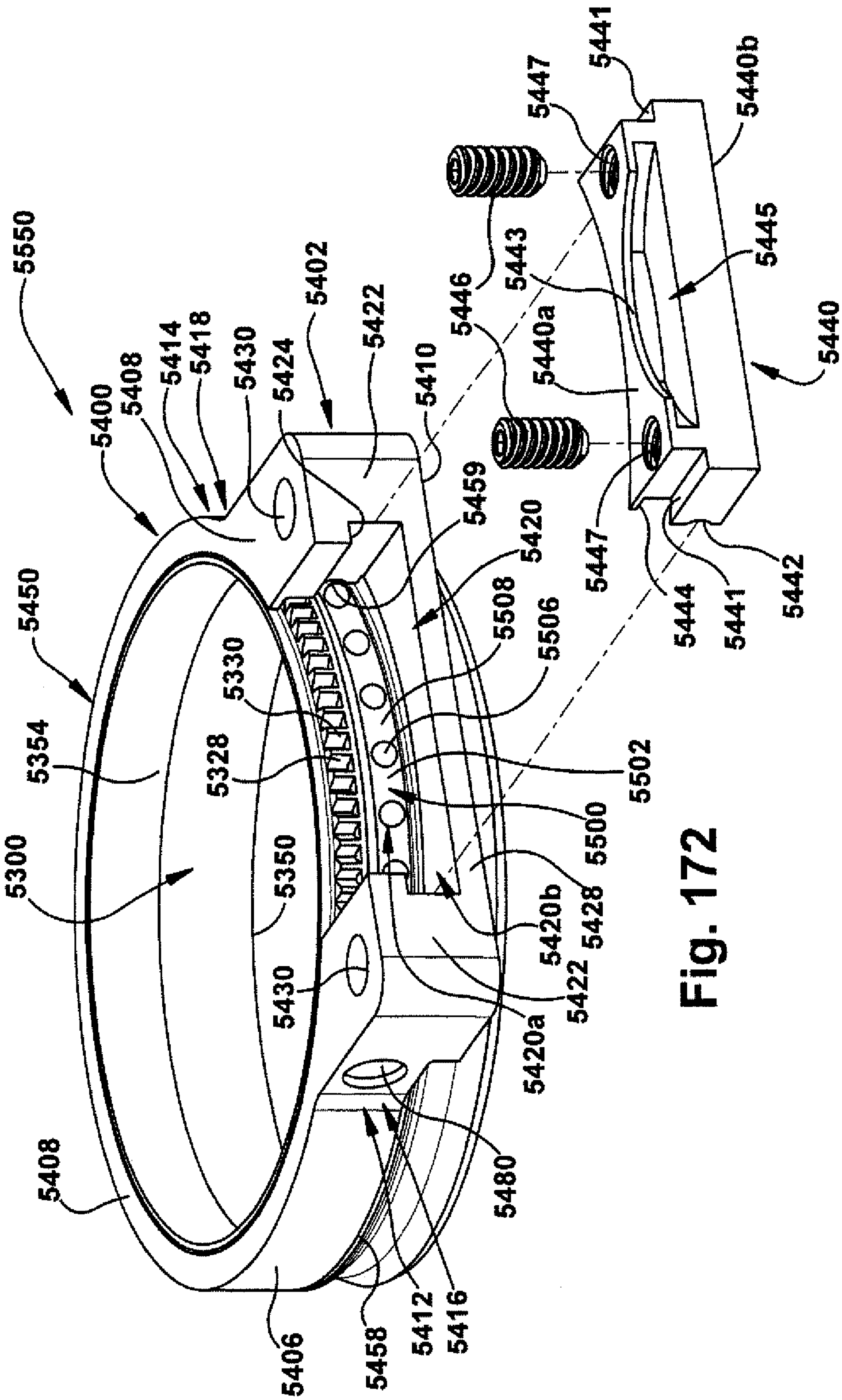
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Fig. 172

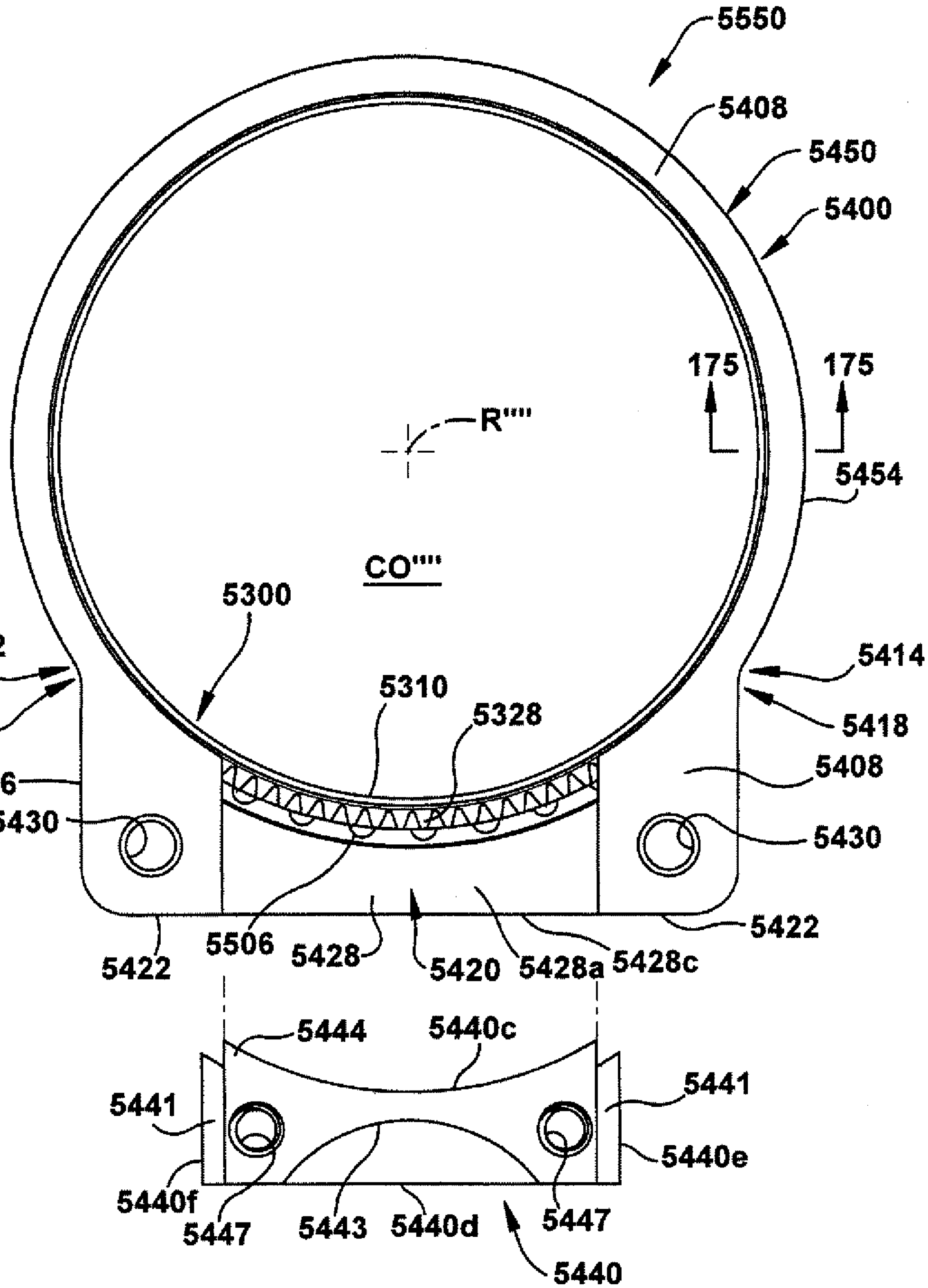

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Fig. 173

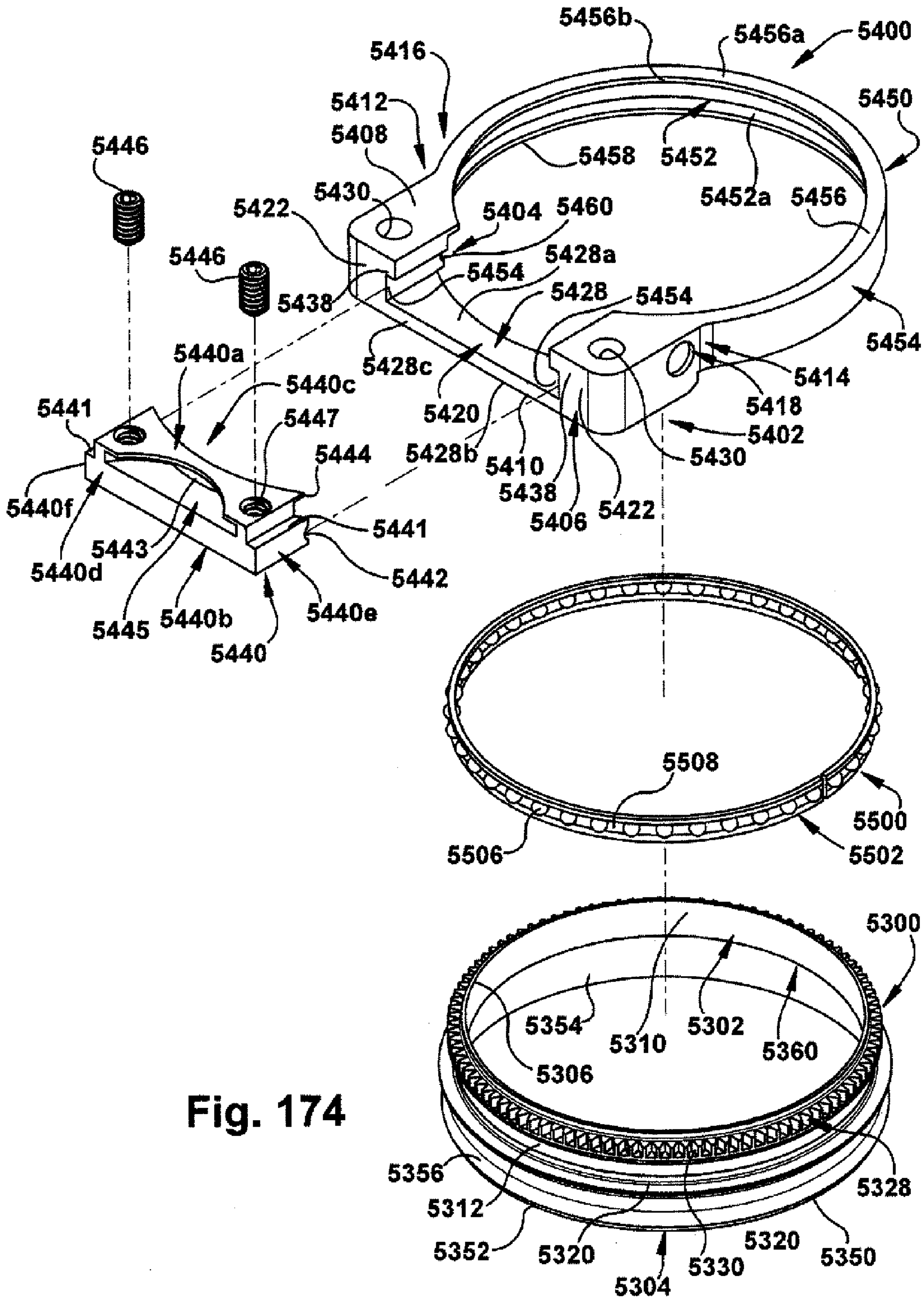
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Fig. 174

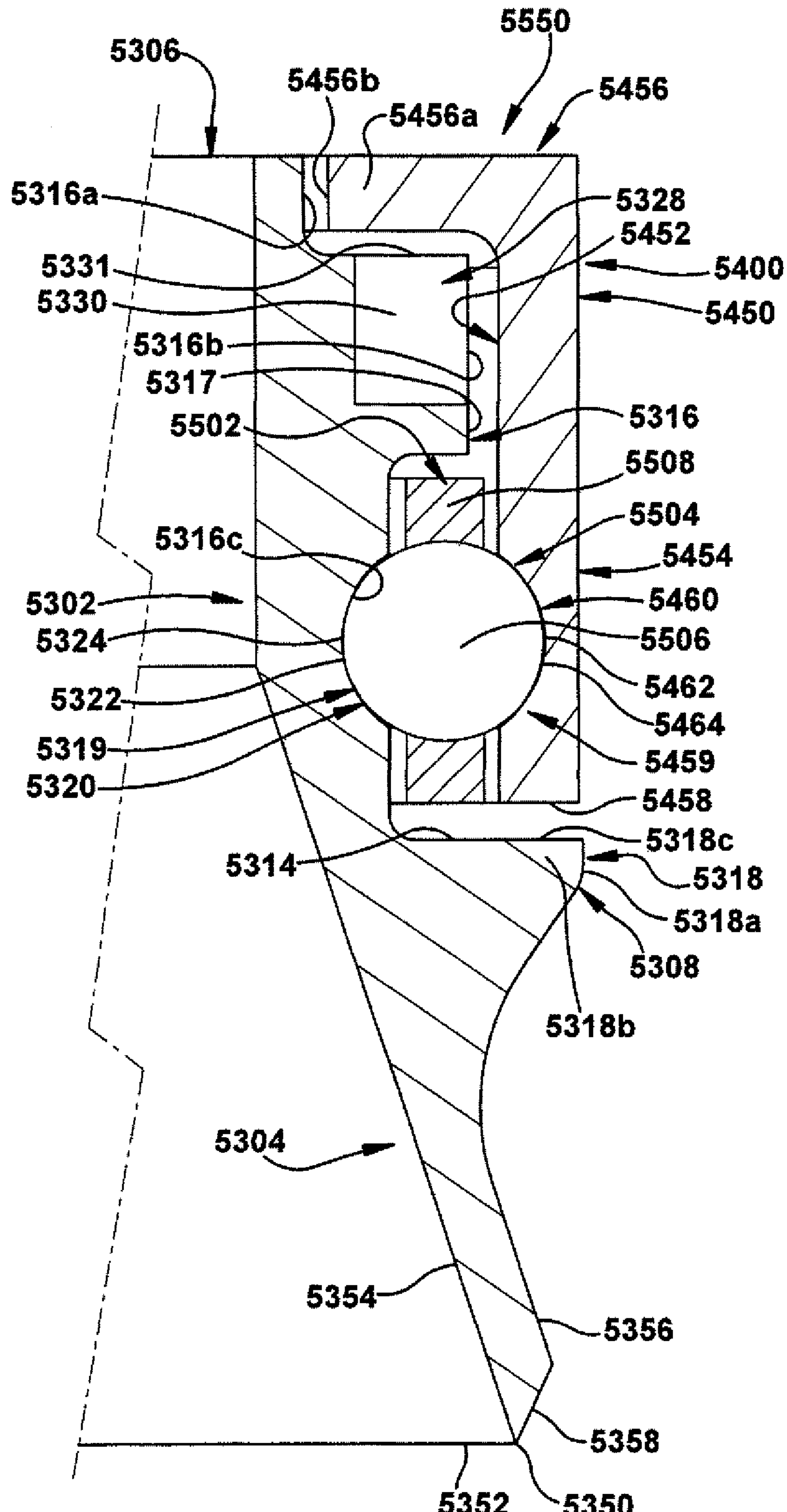
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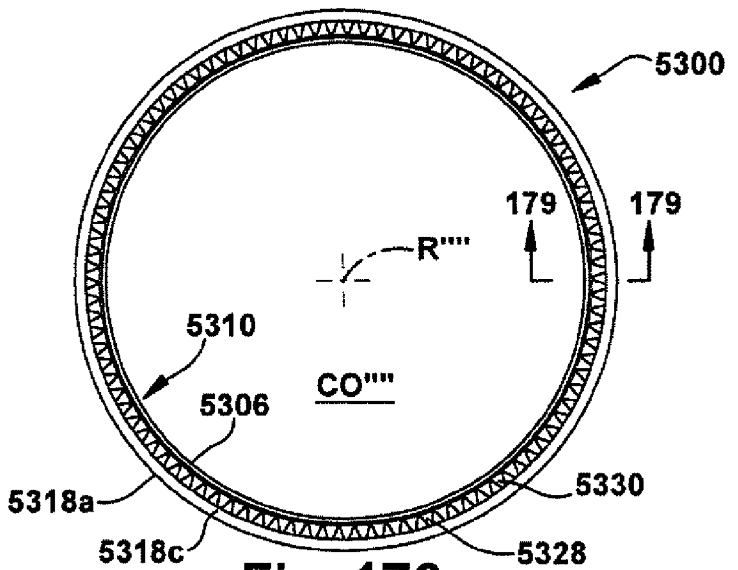
Fig. 175



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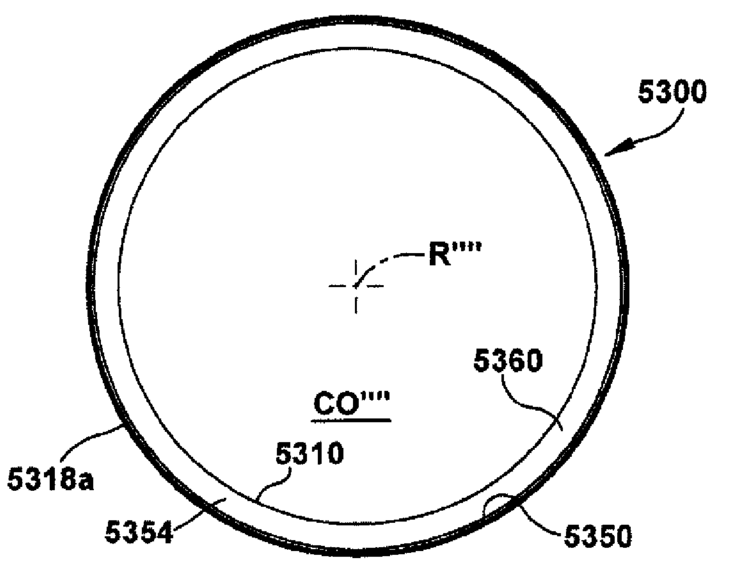

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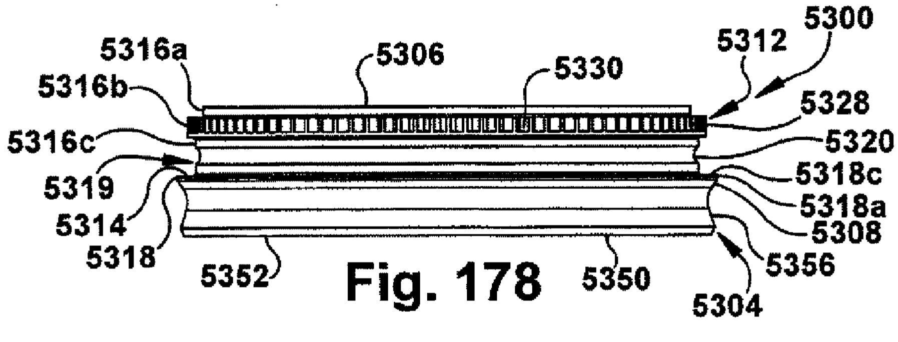

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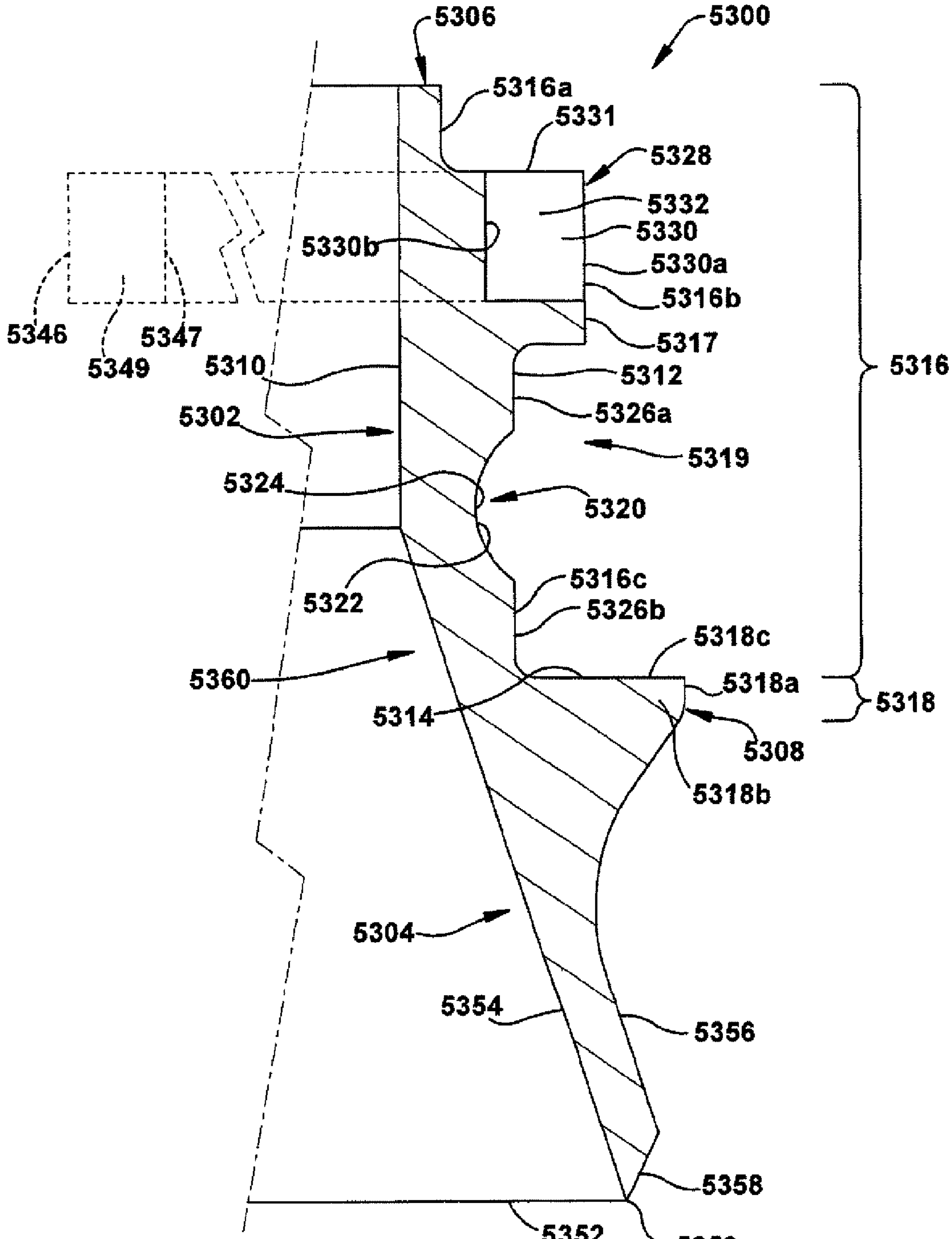
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Fig. 179

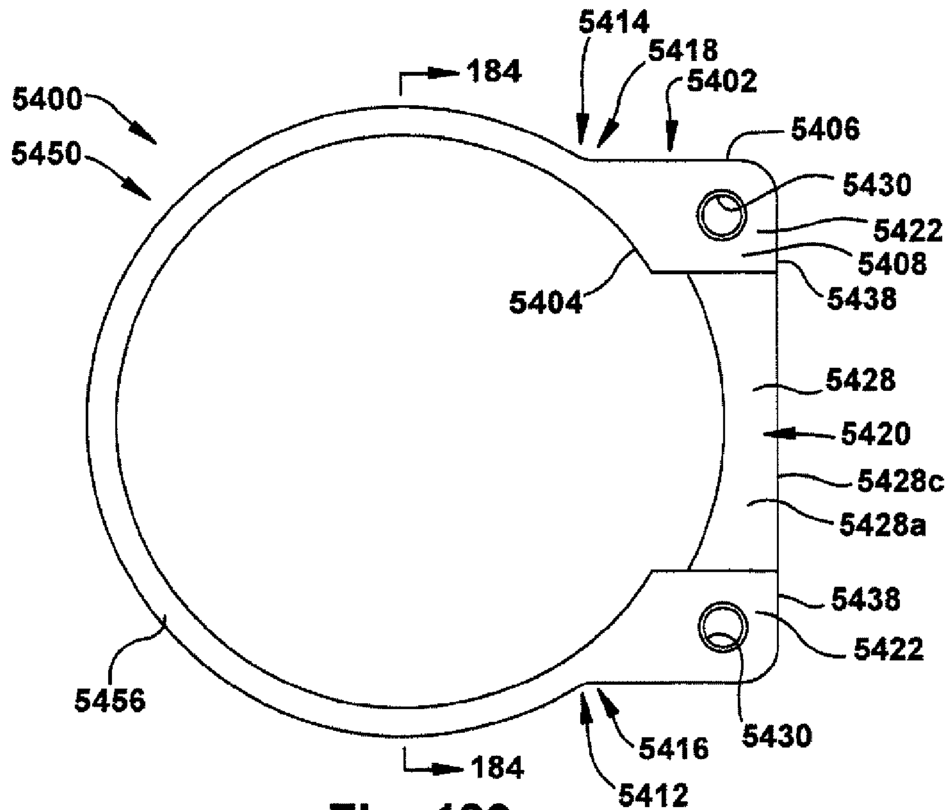
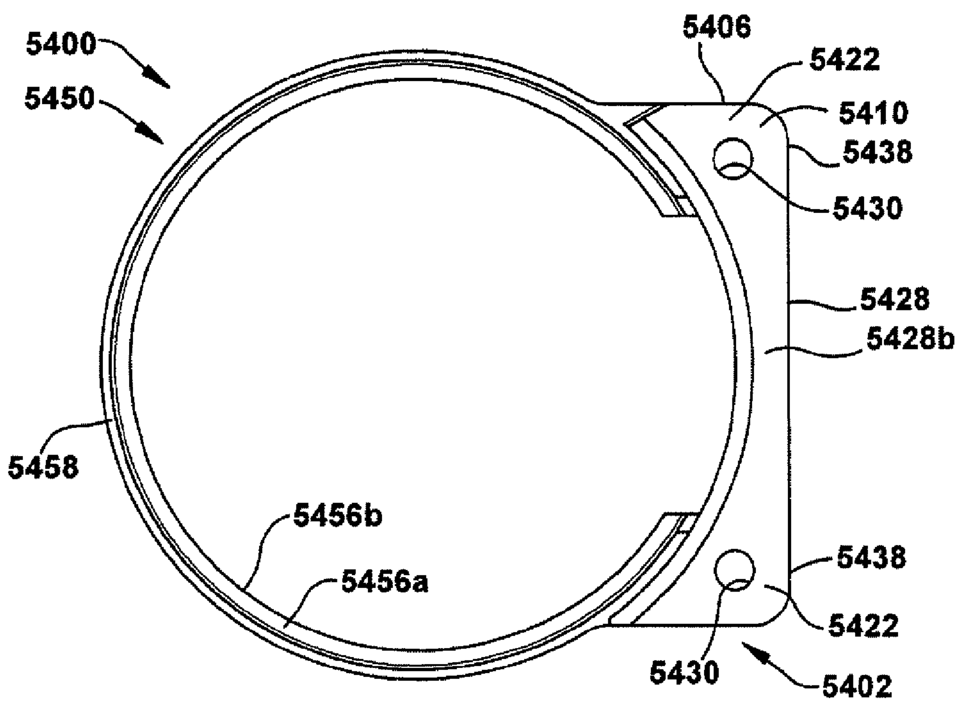


Fig. 180



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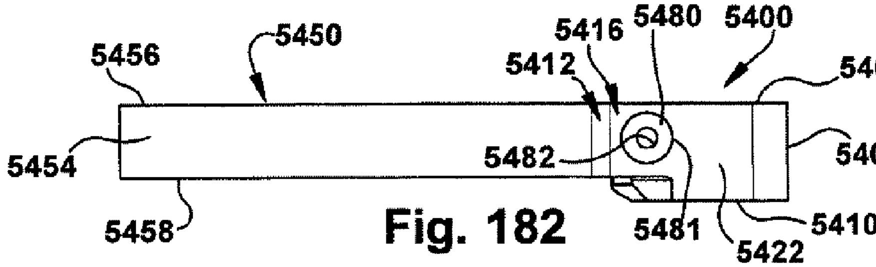

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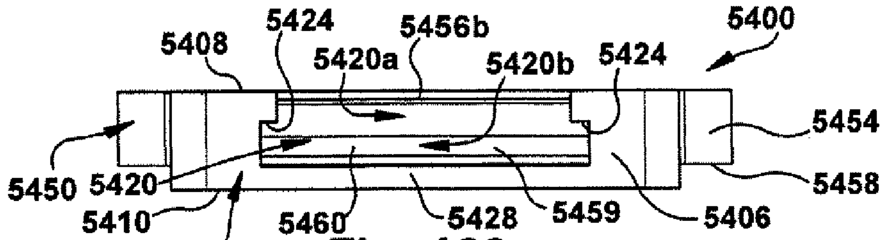

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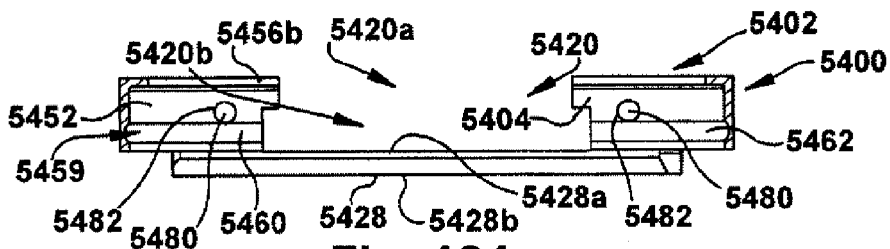

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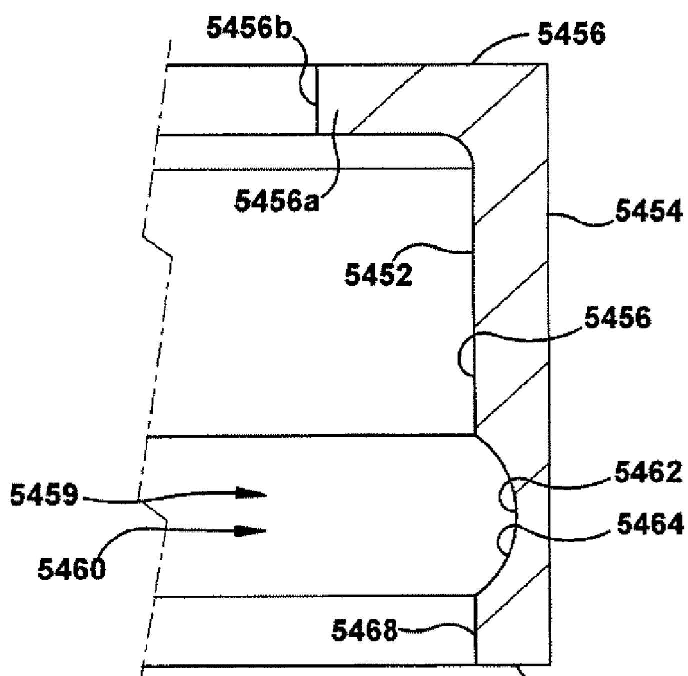

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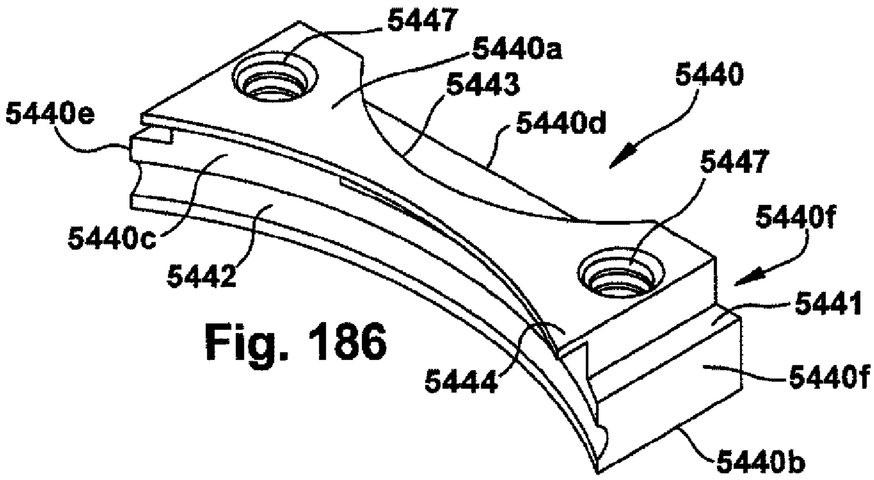

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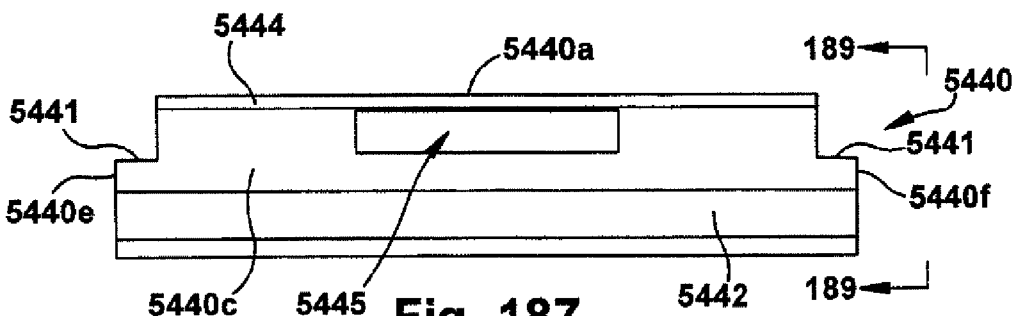

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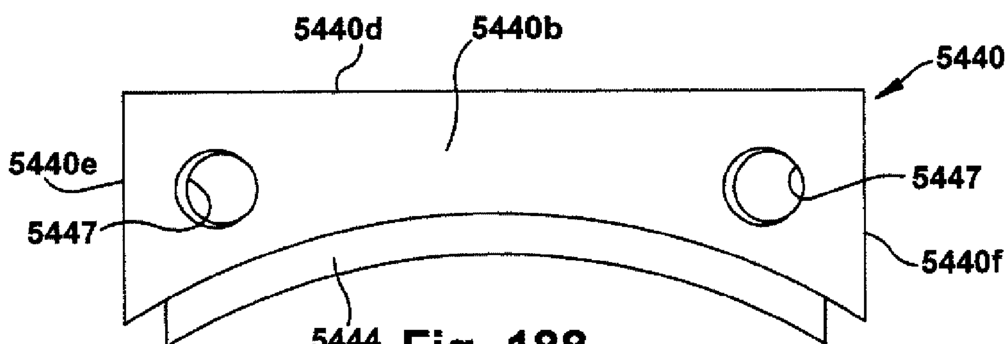

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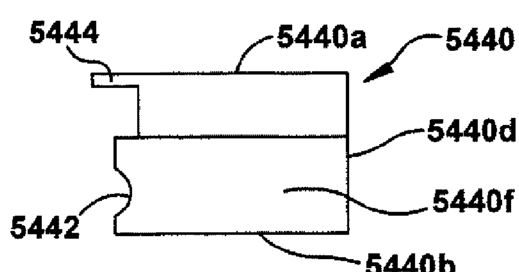

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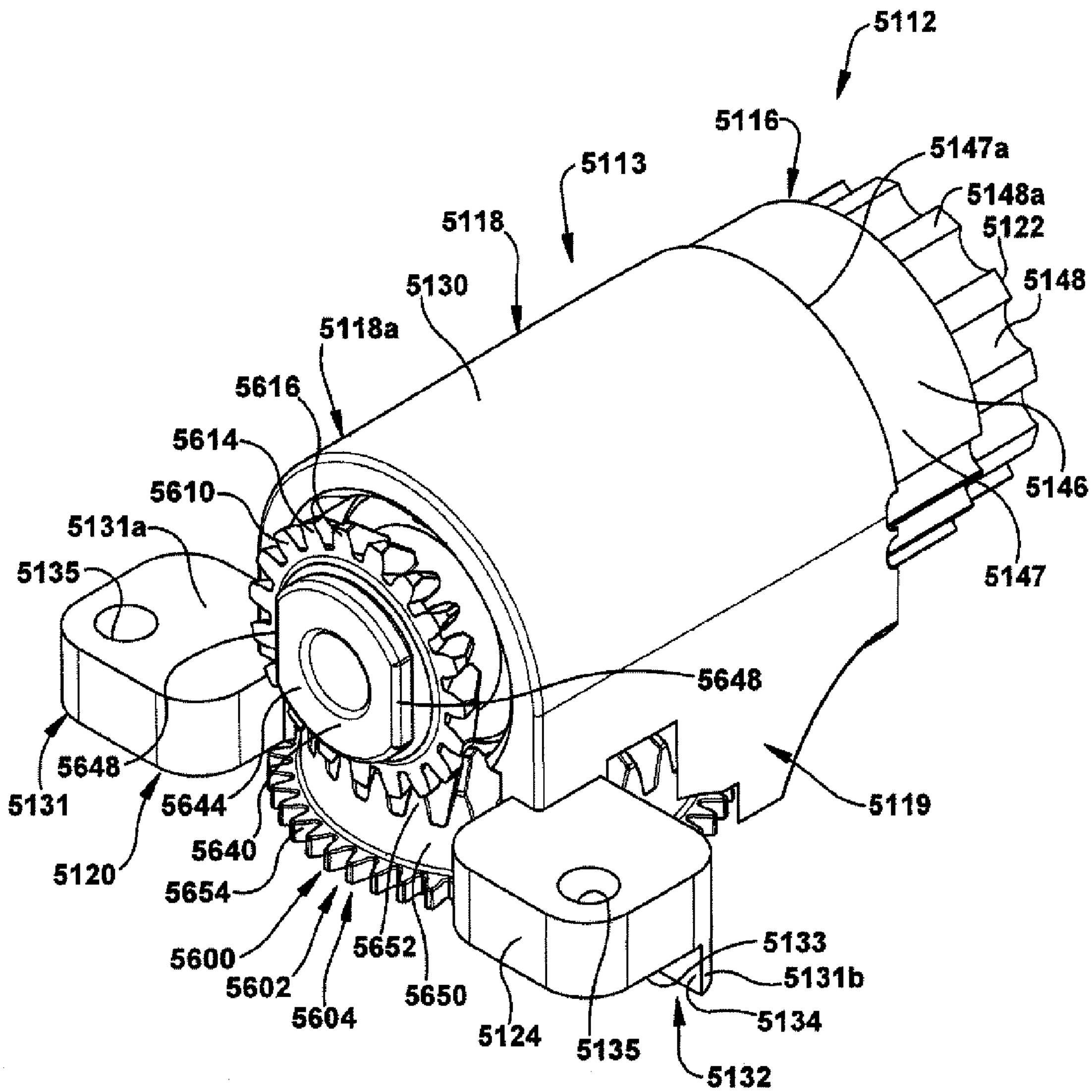
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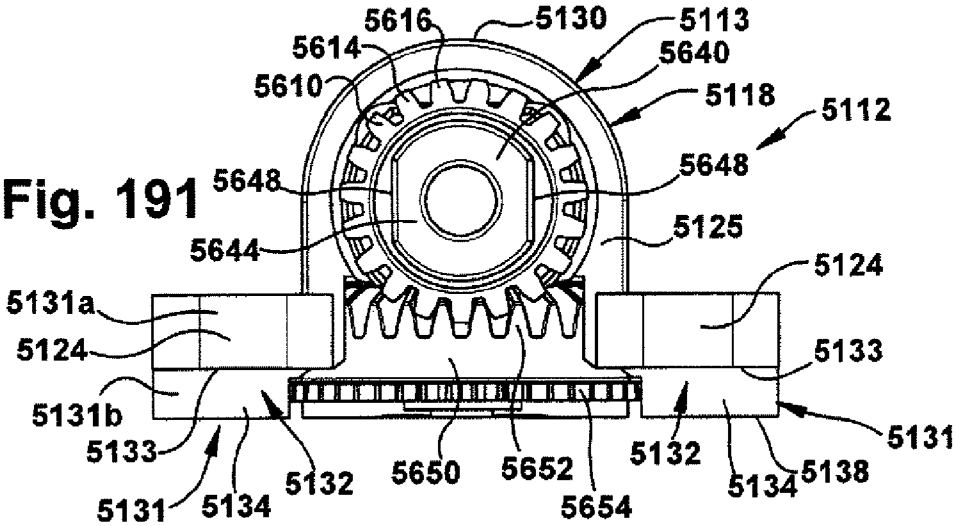
Fig. 190

Fig. 191



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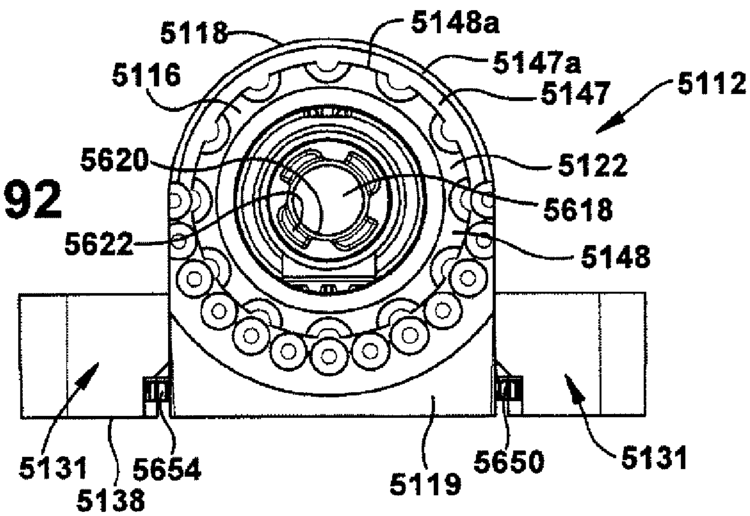


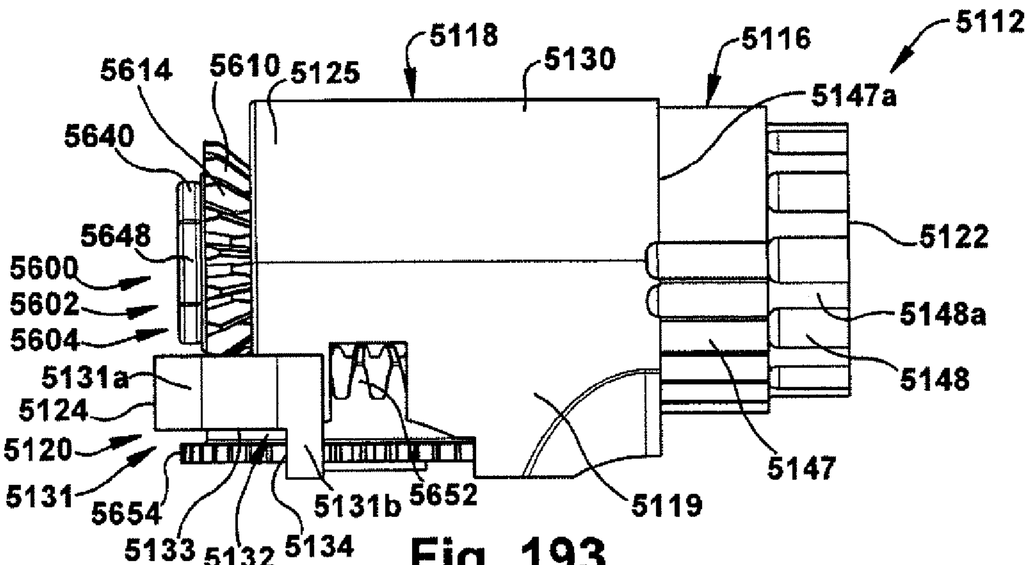
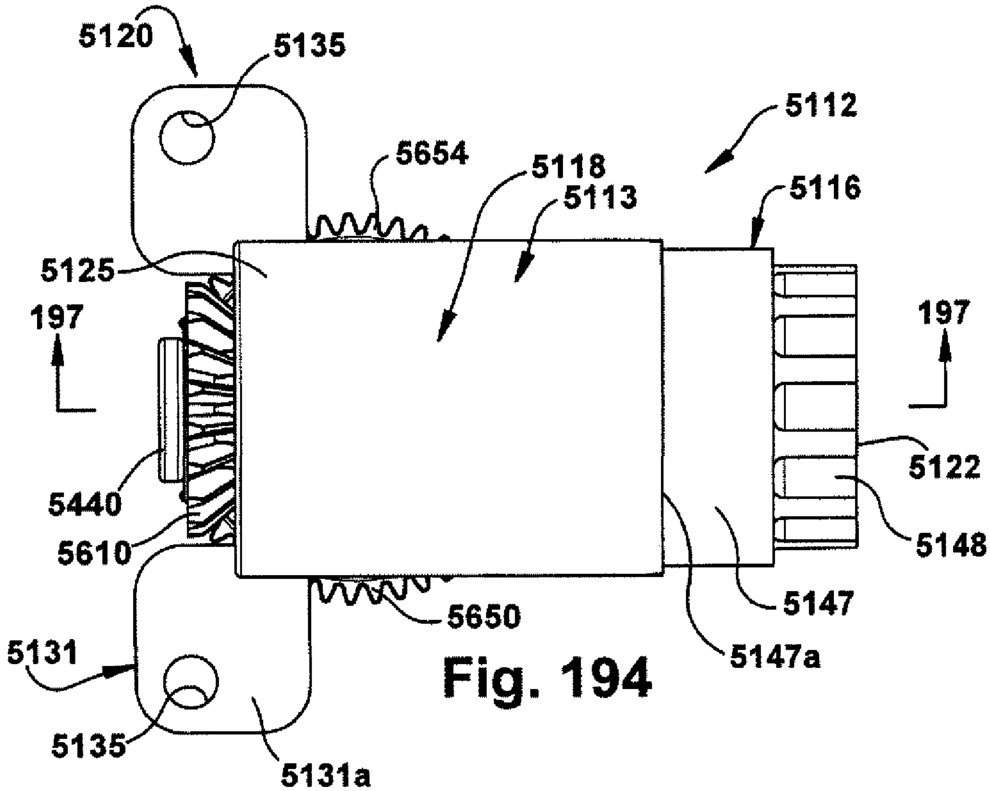


Fig. 193



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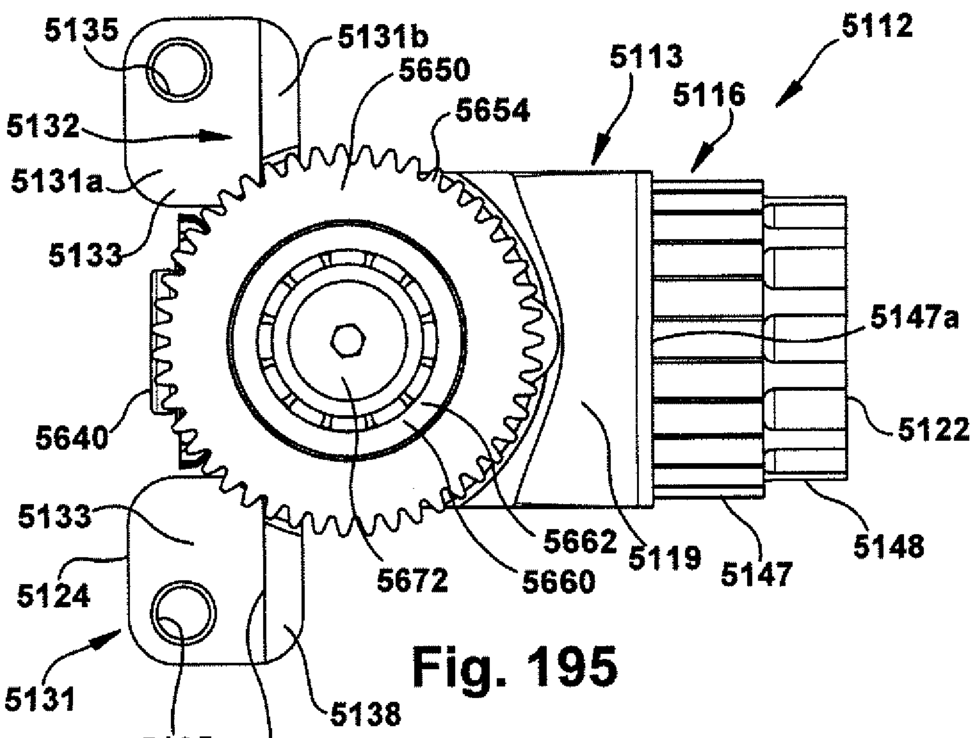

Fig. 195

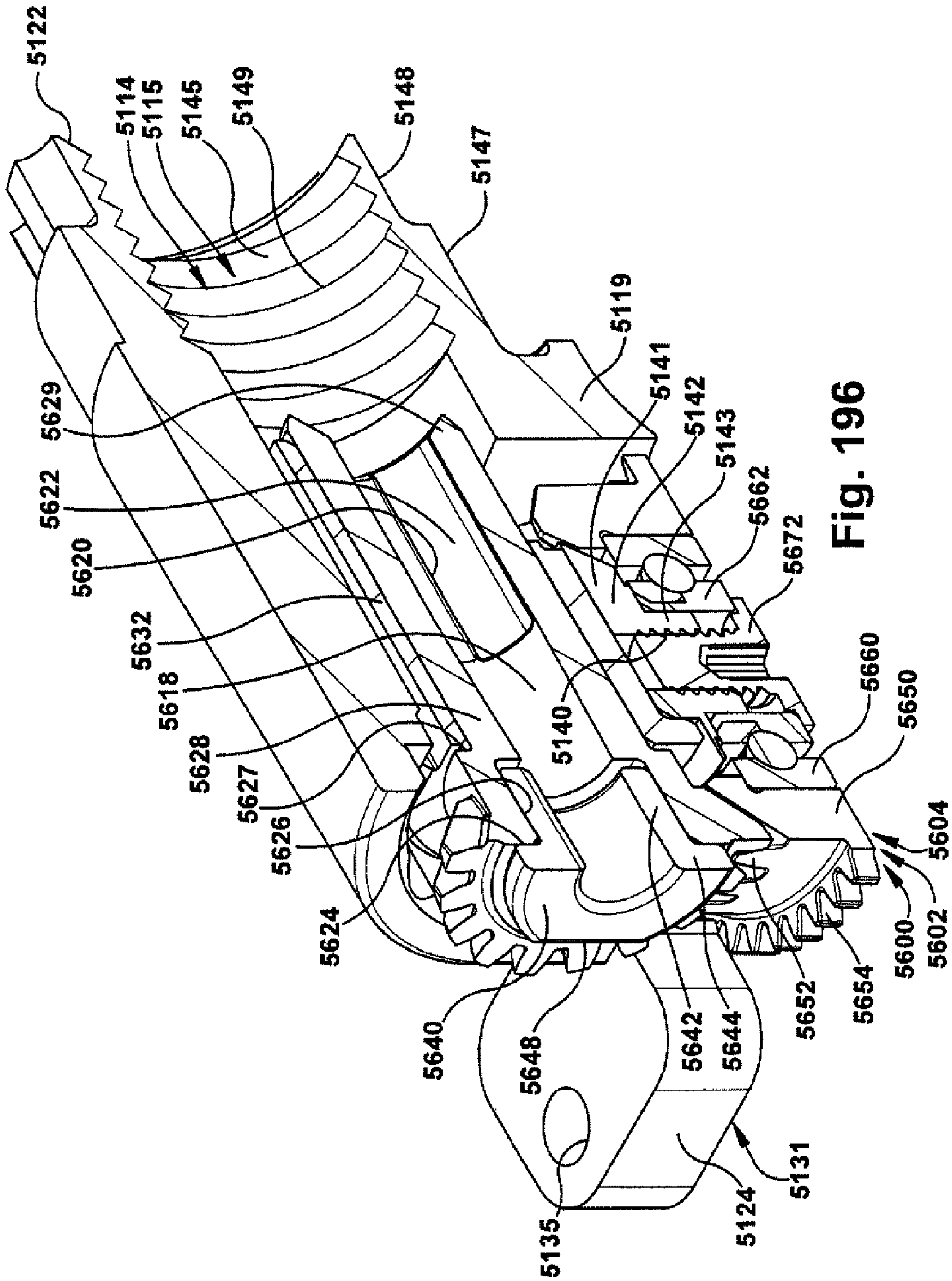
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Fig. 196

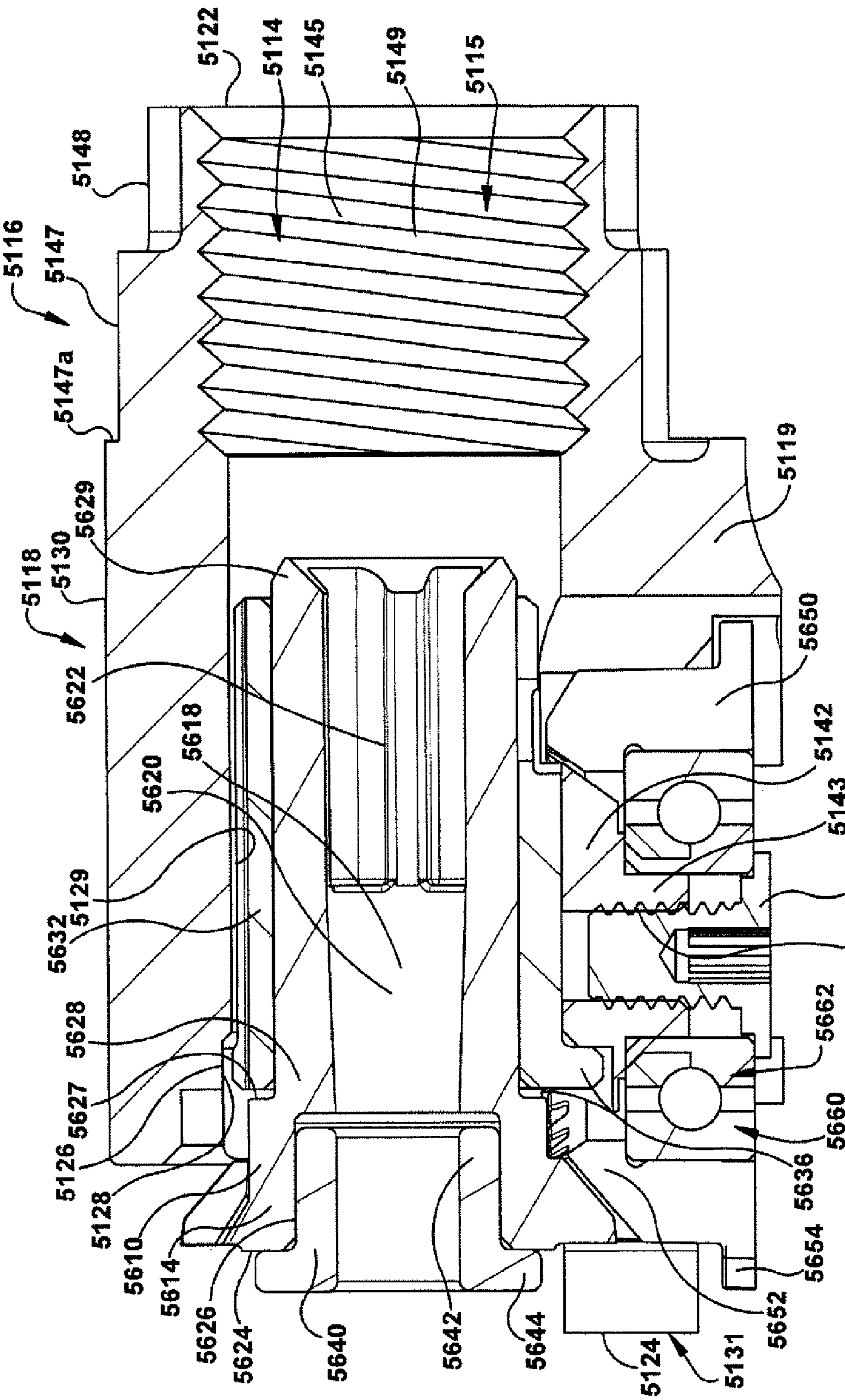
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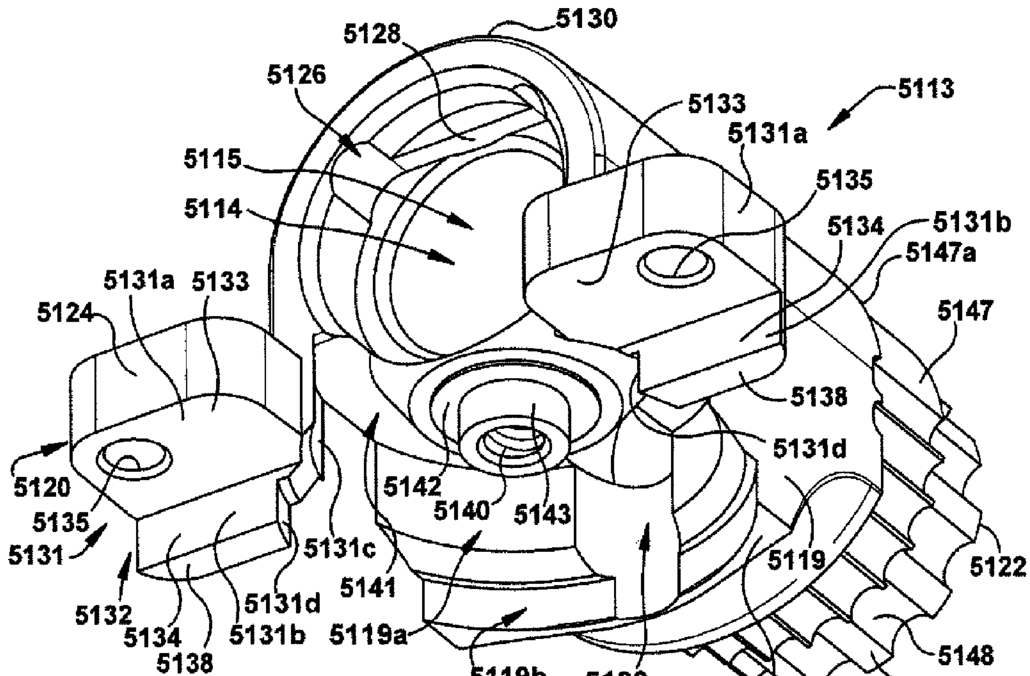
Fig. 197



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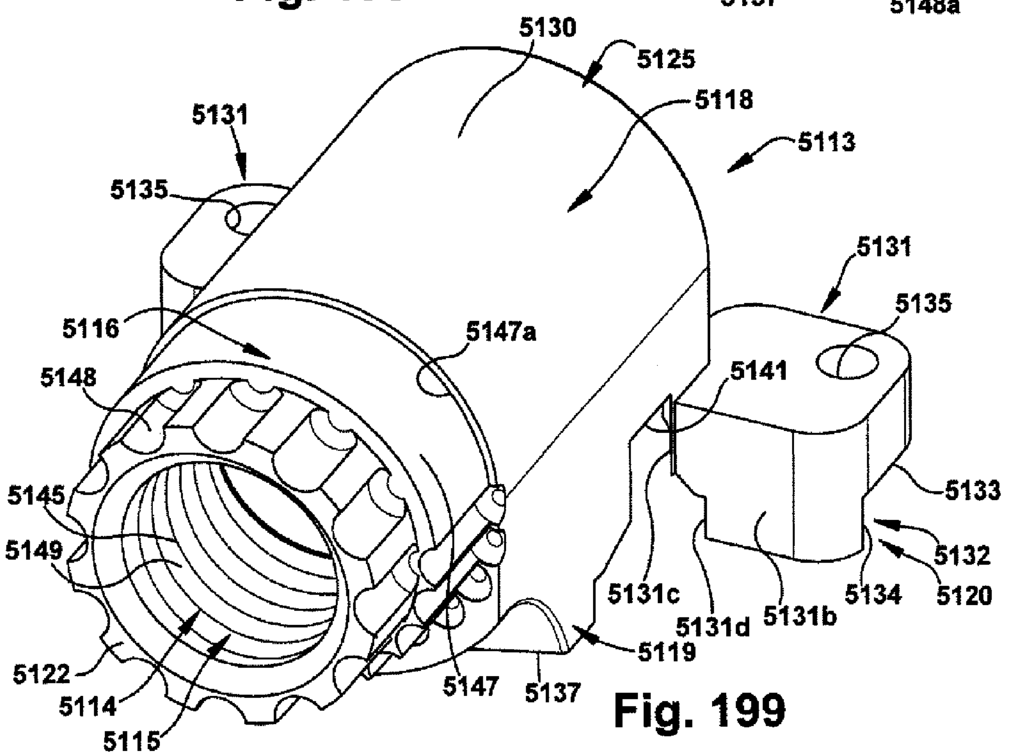

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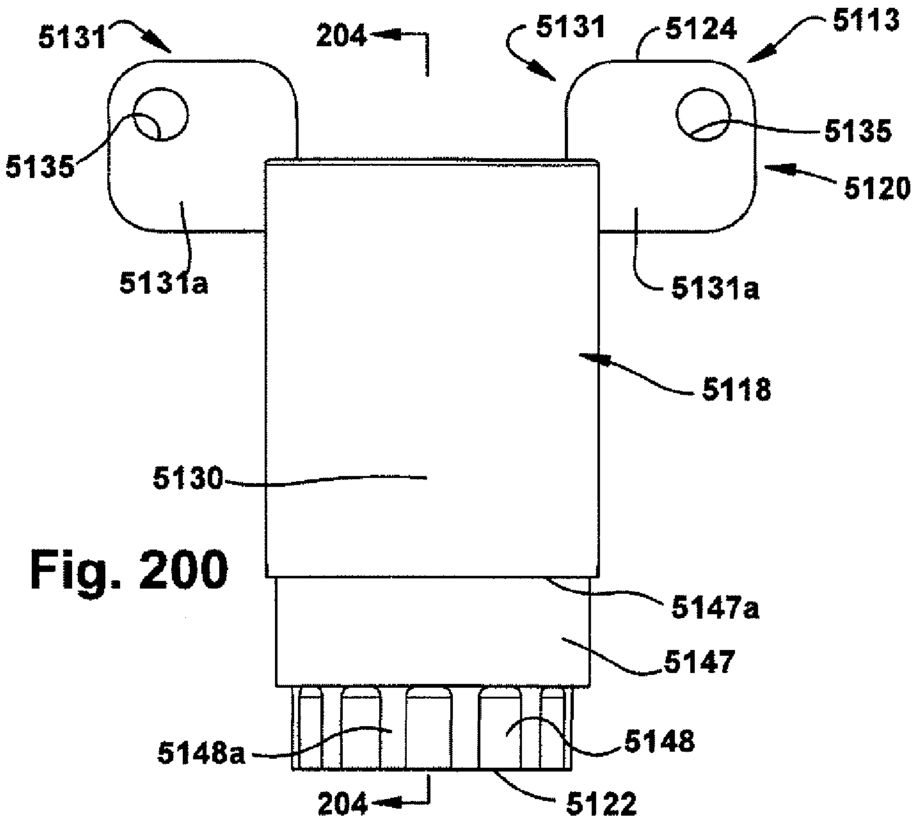

Fig. 200

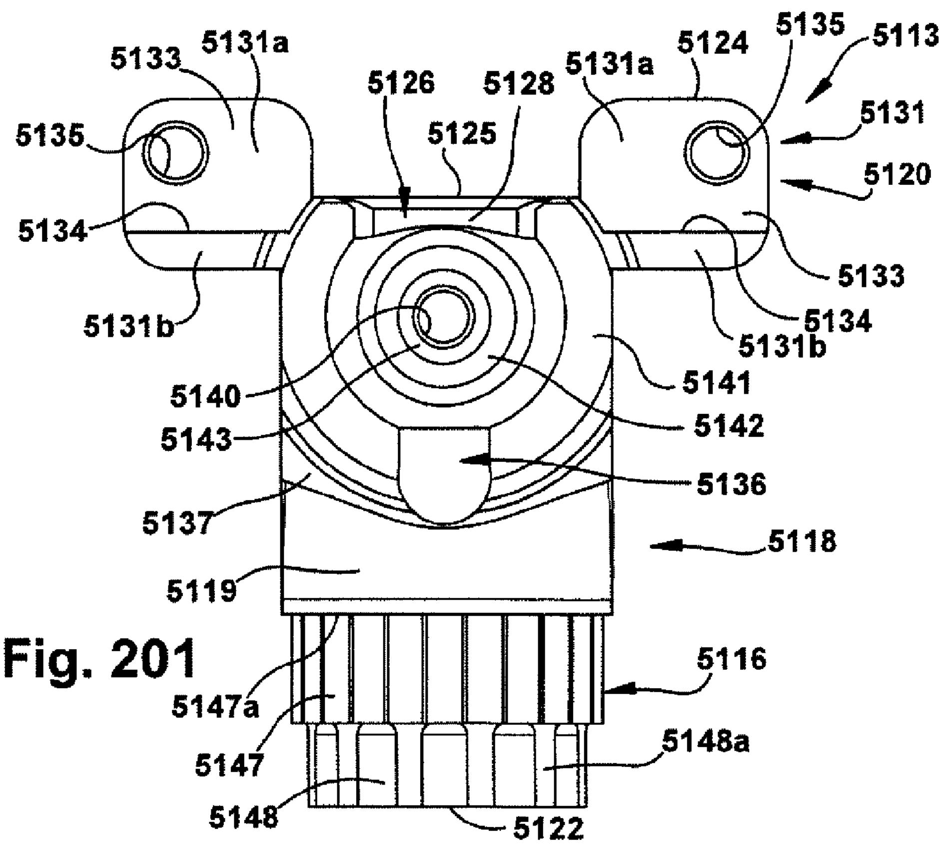

Fig. 201

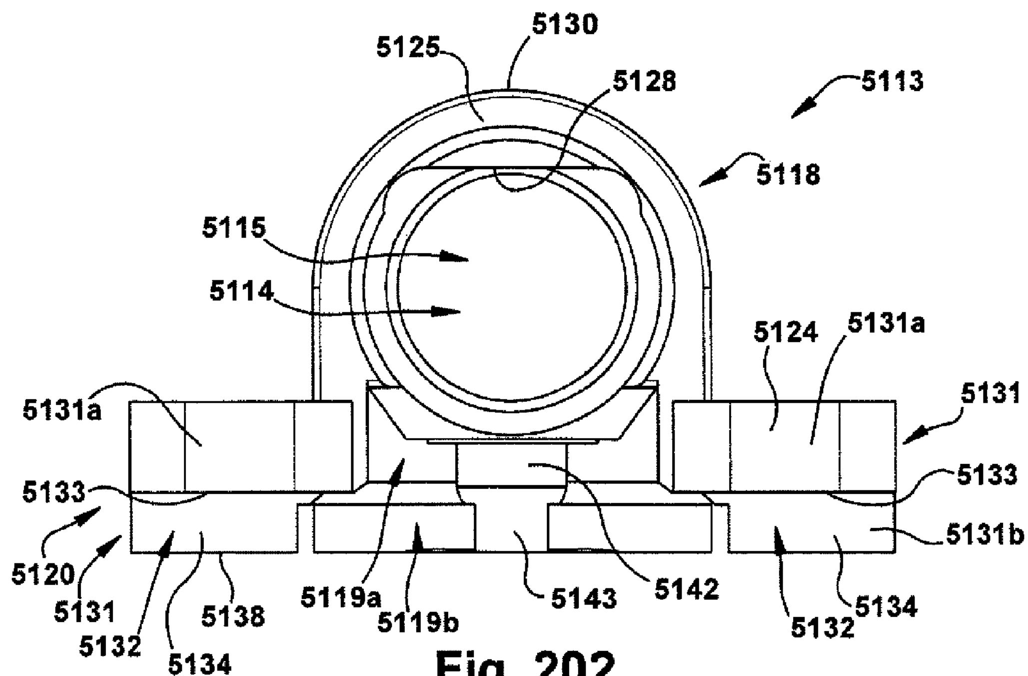

Fig. 202

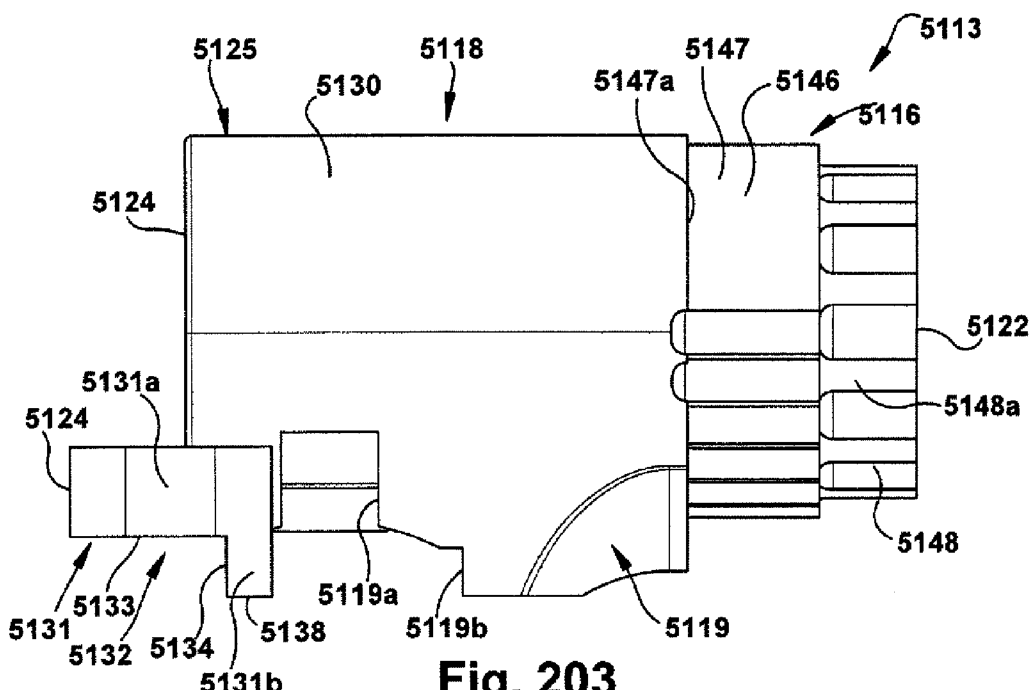

Fig. 203

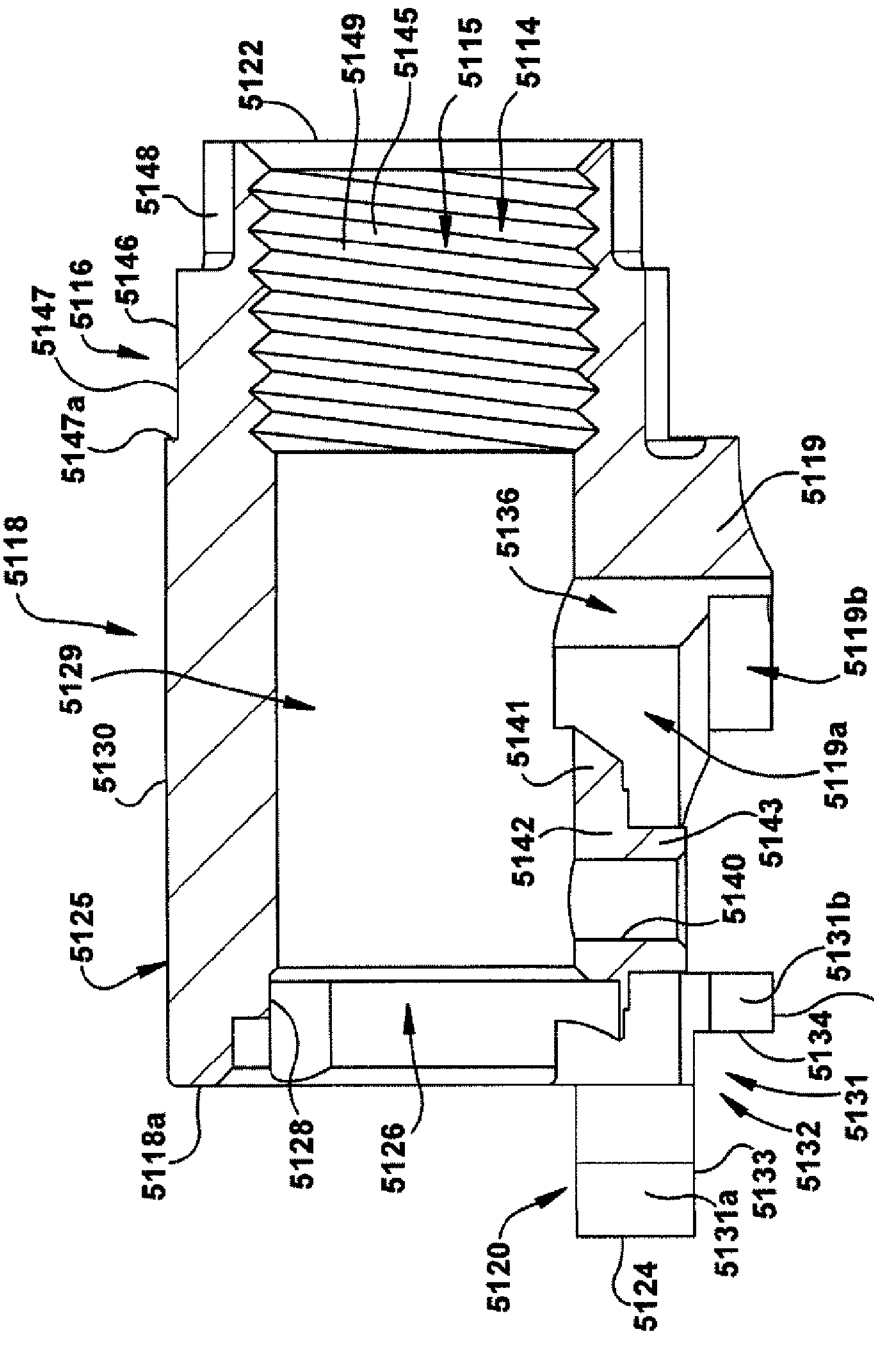
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Fig. 204

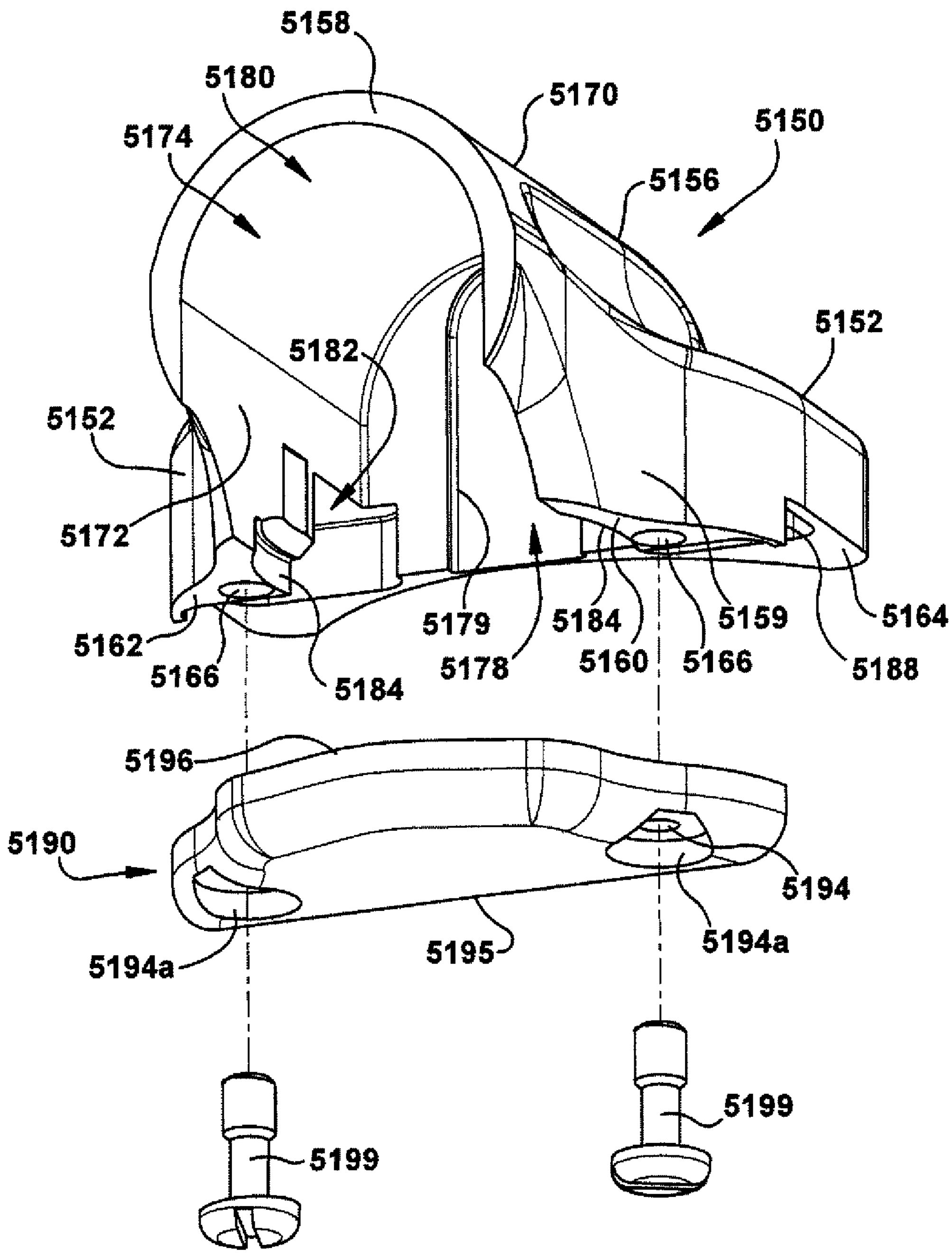
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Fig. 205

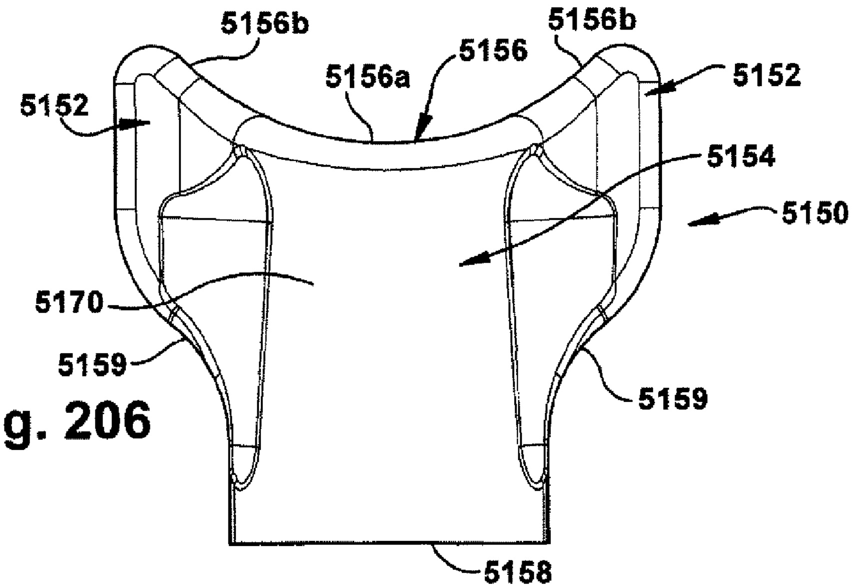

Fig. 206

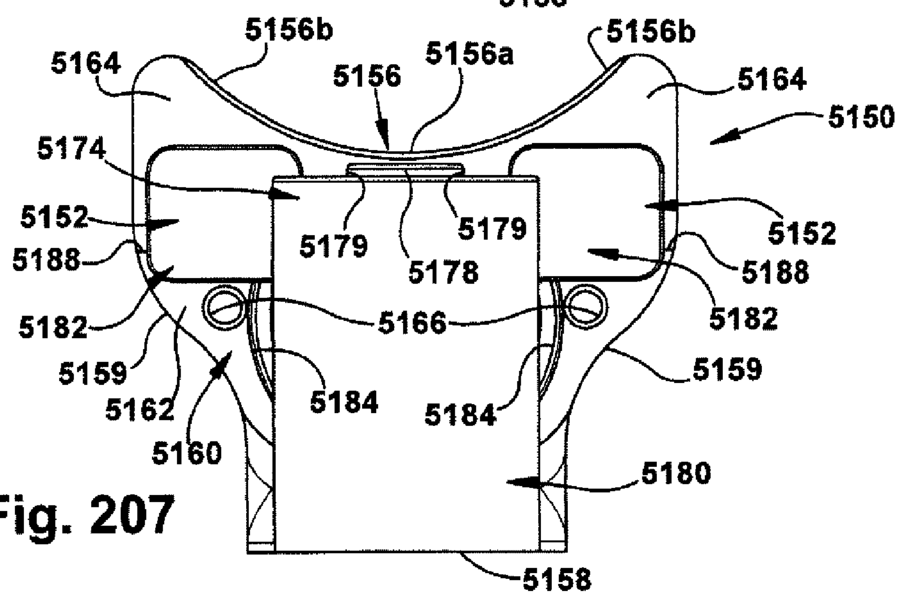

Fig. 207

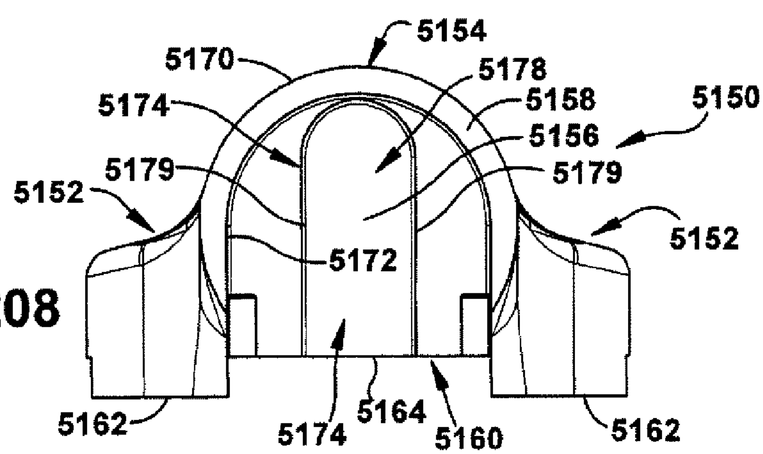

Fig. 208

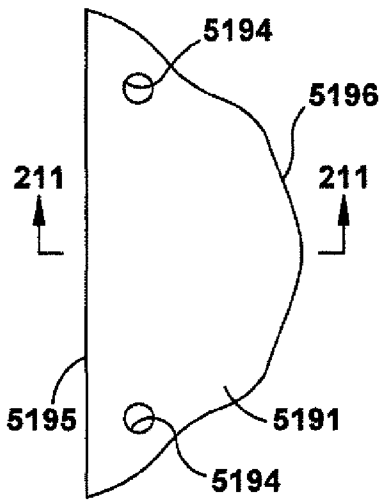

Fig. 209

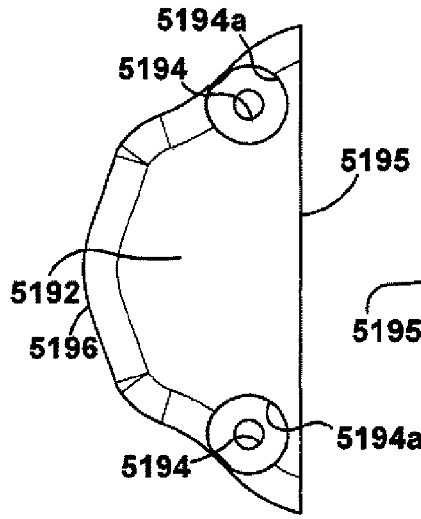

Fig. 210

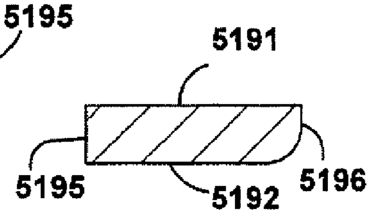

Fig. 211

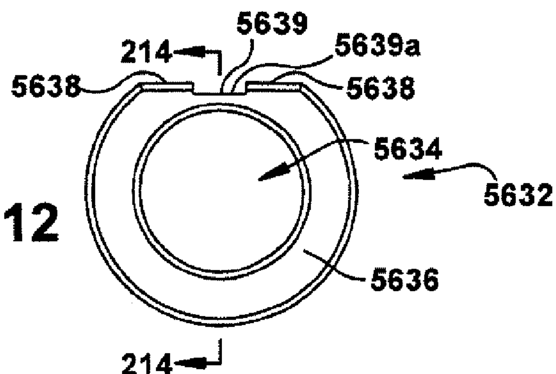

Fig. 212

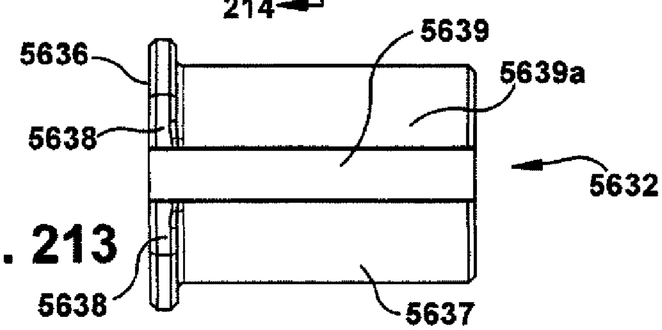

Fig. 213

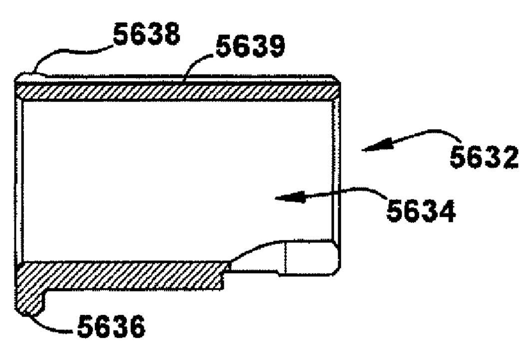

Fig. 214

POWER OPERATED ROTARY KNIFE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and is a continuation of U.S. application Ser. No. 13/189,938, filed on Jul. 25, 2011, published as U.S. Publication No. US-2013-0025138-A1 on Jan. 31, 2013, issued as U.S. Pat. No. 8,726,524 on May 20, 2014. U.S. application Ser. No. 13/189,938 and U.S. Publication No. US-2013-0025138-A1 are incorporated herein in their respective entireties by reference for any and all purposes.

TECHNICAL FIELD

The present disclosure relates to a power operated rotary knife.

BACKGROUND

Power operated rotary knives are widely used in meat processing facilities for meat cutting and trimming operations. Power operated rotary knives also have application in a variety of other industries where cutting and/or trimming operations need to be performed quickly and with less effort than would be the case if traditional manual cutting or trimming tools were used, e.g., long knives, scissors, nippers, etc. By way of example, power operated rotary knives may be effectively utilized for such diverse tasks as taxidermy and cutting and trimming of elastomeric or urethane foam for a variety of applications including vehicle seats.

Power operated rotary knives typically include a handle assembly and a head assembly attachable to the handle assembly. The head assembly includes an annular blade housing and an annular rotary knife blade supported for rotation by the blade housing. The annular rotary blade of conventional power operated rotary knives is typically rotated by a drive assembly which include a flexible shaft drive assembly extending through an opening in the handle assembly. The shaft drive assembly engages and rotates a pinion gear supported by the head assembly. The flexible shaft drive assembly includes a stationary outer sheath and a rotatable interior drive shaft which is driven by a pneumatic or electric motor. Gear teeth of the pinion gear engage mating gear teeth formed on an upper surface of the rotary knife blade.

Upon rotation of the pinion gear by the drive shaft of the flexible shaft drive assembly, the annular rotary blade rotates within the blade housing at a high RPM, on the order of 900-1900 RPM, depending on the structure and characteristics of the drive assembly including the motor, the shaft drive assembly, and a diameter and the number of gear teeth formed on the rotary knife blade. Conventional power operated rotary knives are disclosed in U.S. Pat. No. 6,354,949 to Baris et al., U.S. Pat. No. 6,751,872 to Whited et al., U.S. Pat. No. 6,769,184 to Whited, and U.S. Pat. No. 6,978,548 to Whited et al., all of which are assigned to the assignee of the present invention and all of which are incorporated herein in their respective entireties by reference.

SUMMARY

In one aspect, the present disclosure relates a power operated rotary knife comprising: an annular rotary knife blade including a wall defining a knife blade bearing surface; a blade housing including a wall defining a blade housing bearing surface; and a blade-blade housing bearing structure disposed between the knife blade bearing surface and the blade housing bearing surface, the blade-blade housing bearing structure supporting the knife blade for rotation with respect to the blade housing about a knife blade central axis, the blade-blade housing bearing structure including an elongated rolling bearing strip that extends circumferentially around the knife blade central axis between the knife blade bearing surface and the blade housing bearing surface. In one exemplary embodiment, the elongated rolling bearing strip comprises a plurality of rolling bearings disposed in spaced apart relation and a flexible separator cage for positioning the plurality of spaced apart rolling bearings.

In another aspect, the present disclosure relates to a support structure for use with a power operated rotary knife including an annular rotary knife blade rotating about a central axis and an annular blade housing, the support structure disposed between a knife blade bearing surface and a blade housing bearing surface to secure and rotatably support the knife blade with respect to the blade housing, the support structure comprising: an elongated rolling bearing strip having a plurality of rolling bearings disposed in spaced apart relation and a flexible separator cage for positioning the plurality of spaced apart rolling bearings, the rolling bearing strip extending circumferentially between the knife blade bearing surface and the blade housing bearing surface, the separator cage forming at least a portion of a circle and each of the plurality of rolling bearings extending radially from the separator cage and adapted to contact the knife blade bearing surface and the blade housing bearing surface.

In another aspect, the present disclosure relates to a method of supporting an annular knife blade for rotation about a central axis in a blade housing of a power operated rotary knife, the method comprising: aligning a knife blade and blade housing such that a bearing surface of the knife blade is in radial alignment with a bearing surface of the blade housing, the knife blade bearing surface and the blade housing bearing surface defining an annular passageway; and routing a rolling bearing strip along the annular passageway such that the strip extends circumferentially around the knife blade central axis between the knife blade bearing surface and the blade housing bearing surface forming at least a portion of a circle about the central axis.

In another aspect, the present disclosure relates to a power operated rotary knife comprising: a head assembly including a gearbox assembly, an annular rotary knife blade, a blade housing, and a blade-blade housing bearing structure; the blade housing coupled to the gearbox assembly and including an annular blade support section defining a bearing surface formed on an inner wall of the annular blade support section; the annular rotary knife blade including a body and a blade section extending axially from the body, the body including a first, upper end and a lower, second end spaced axially apart and an inner wall and an outer wall spaced radially apart, the blade section extending from the lower end of the body, the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and from the knife blade bearing surface; the blade-blade housing bearing structure disposed between the knife blade bearing surface and the blade housing bearing surface; and a gear train of the gearbox assembly, the gear train including a drive gear having a plurality of gear teeth that mesh with the set of gear teeth of the knife blade to rotate the knife blade with respect to the blade housing.

In another aspect, the present disclosure relates to an annular rotary knife blade for rotation about a central axis in a power operated rotary knife, the rotary knife blade comprising: an annular rotary knife blade including a body and a

blade section extending axially from the body, the body including a first upper end and a second lower end spaced axially apart and an inner wall and an outer wall spaced radially apart; the blade section extending from the lower end of the body; and the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and axially spaced from the knife blade bearing surface.

In another aspect, the present disclosure relates to a power operated rotary knife comprising: a gearbox assembly including a gearbox housing and a gearbox; a blade housing coupled to the gearbox housing; and an annular rotary knife blade including an upper end and an axially spaced apart lower end, the lower end defining a cutting edge of the blade, the knife blade further including an outer wall defining a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the knife blade, the knife blade rotating about a central axis with respect to the blade housing; the gearbox comprising a gear train including a pinion gear and a drive gear, the pinion gear engaging and rotating the drive gear and the drive gear engaging and rotating the knife blade about the central axis; and the drive gear comprising a double gear including a first gear engaging and being rotated by the pinion gear about a rotational axis of the drive gear and a second gear engaging the set of gear teeth of the knife blade to rotate the knife blade about the central axis, the first and second gears of the drive gear being concentric with the drive gear rotational axis.

In another aspect, the present disclosure relates to a gear train supported in a gearbox housing of a power operated rotary knife to rotate an annular rotary knife blade about a central axis, the gear train comprising: a pinion gear and drive gear wherein the pinion gear engages and rotates the drive gear and the drive gear is configured to engage and rotate an annular rotary knife blade; and wherein the drive gear comprises a double gear including a first gear engaging and being rotated by the pinion gear about a rotational axis of the drive gear and a second gear configured to engage an annular rotary knife blade, the first and second gears of the drive gear being concentric with the drive gear rotational axis.

In another aspect, the present disclosure relates to an annular blade housing for a power operated rotary knife, the blade housing comprising an inner wall and an outer wall, the inner wall defining a blade housing bearing surface, the blade housing further including a cleaning port having an entry opening and exit opening, the exit opening being in the inner wall and in fluid communication with the blade housing bearing surface.

In another aspect, the present disclosure relates to a power operated rotary knife power operated rotary knife comprising: an annular rotary knife blade including a wall defining a knife blade bearing surface; an annular blade housing comprising an inner wall and an outer wall, the inner wall defining a blade housing bearing surface on the inner wall; a blade-blade housing bearing structure disposed between the knife blade bearing surface and the blade housing bearing surface, the blade-blade housing bearing structure supporting the knife blade for rotation with respect to the blade housing about a knife blade central axis; and the blade housing further including a cleaning port extending radially between the inner wall and the outer wall, cleaning port including an entry opening and an exit opening, the exit opening being in the inner wall and in fluid communication with the blade housing bearing surface.

In another aspect, the present disclosure relates to an annular blade housing for a power operated rotary knife, the blade housing comprising an inner wall and an outer wall, the inner wall defining a blade housing bearing surface, the blade housing further including a blade housing plug opening extending between and through the inner wall and the outer wan, an end of the blade housing plug opening at the inner wall intersecting the blade housing bearing surface to provide access to the blade housing bearing surface through the blade housing plug opening, and a blade housing plug configured to be releasably secured within the blade housing plug opening.

In another aspect, the present disclosure relates to a power operated rotary knife comprising: an annular rotary knife blade including a wall defining a knife blade bearing surface; an annular blade housing comprising an inner wall and an outer wall, the inner wall defining a blade housing bearing surface; a blade-blade housing bearing structure disposed between the knife blade bearing surface and the blade housing bearing surface, the blade-blade housing bearing structure supporting the knife blade for rotation with respect to the blade housing about a knife blade central axis; and wherein the blade housing further includes a blade housing plug opening extending between and through the inner wall and the outer wall, an end of the blade housing plug opening at the inner wall intersecting the blade housing bearing surface to provide access to the blade housing bearing surface through the blade housing plug opening, and a blade housing plug configured to be releasably secured within the blade housing plug opening.

In another aspect, the present disclosure relates to an annular blade housing comprising an inner wall and an outer wall, a section of the inner wall defining a blade housing bearing surface, the blade housing bearing surface being axially spaced from opposite first and second ends of the inner wall, the blade housing further including a projection at one of the first and second ends of the inner wall, the projection extending radially inwardly with respect to the section of the inner wall defining the blade housing bearing surface.

In another aspect, the present disclosure relates to a power operated rotary knife comprising: an annular rotary knife blade including a wall defining a knife blade bearing surface; an annular blade housing comprising an inner wall and an outer wall, the inner wall defining a blade housing bearing surface; a blade-blade housing bearing structure disposed between the knife blade bearing surface and the blade housing bearing surface, the blade-blade housing bearing structure supporting the knife blade for rotation with respect to the blade housing about a knife blade central axis; and wherein the blade housing further includes a projection at one of the first and second ends of the inner wall, the projection extending radially inwardly with respect to the section of the inner wall defining the blade housing bearing surface.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of the present disclosure will become apparent to one skilled in the art to which the present disclosure relates upon consideration of the following description of the disclosure with reference to the accompanying drawings, wherein like reference numerals, unless otherwise described refer to like parts throughout the drawings and in which:

FIG. **1** is a schematic front perspective view of a first exemplary embodiment of a power operated rotary knife of the present disclosure including a head assembly, a handle assembly and a drive mechanism, the head assembly including a gearbox assembly, an annular rotary knife blade, a blade housing, and a blade-blade housing support or bearing structure and the handle assembly including a hand piece and a hand piece retaining assembly;

FIG. **2** is a schematic exploded perspective view of the power operated rotary knife of FIG. **1**;

FIG. **2**A is a schematic exploded perspective view of a portion of the head assembly of the power operated rotary knife of FIG. **1** including the rotary knife blade, the blade housing and the blade-blade housing bearing structure that, in one exemplary embodiment, includes an elongated rolling bearing strip that secures and rotatably supports the rotary knife blade with respect to the blade housing;

FIG. **2**B is a schematic exploded perspective view of the handle assembly of the power operated rotary knife of FIG. **1** including the hand piece, the hand piece retaining assembly and a drive shaft latching assembly supported by the hand piece retaining assembly;

FIG. **2**C is a schematic exploded perspective view of a portion of the head assembly of the power operated rotary knife of FIG. **1** including the gearbox assembly, a steeling assembly and a frame body, the gearbox assembly including a gearbox and a gearbox housing;

FIG. **3** is a schematic top plan view of the power operated rotary knife of FIG. **1**;

FIG. **4** is a schematic bottom plan view of the power operated rotary knife of FIG. **1**;

FIG. **5** is a schematic front elevation view of the power operated rotary knife of FIG. **1**;

FIG. **6** is a schematic rear elevation view of the power operated rotary knife of FIG. **1**;

FIG. **7** is a schematic right side elevation view of the power operated rotary knife of FIG. **1**, as viewed from a front or rotary knife blade end of the power operated knife;

FIG. **8** is a schematic section view taken along a longitudinal axis of the handle assembly of the power operated rotary knife of FIG. **1**, as seen from a plane indicated by the line **8-8** in FIG. **3**;

FIG. **8**A is a schematic enlarged section view of a portion of the handle assembly shown in FIG. **8** that is within a dashed circle labeled FIG. **8**A in FIG. **8**;

FIG. **9** is a schematic perspective section view along the longitudinal axis of the handle assembly of the power operated rotary knife of FIG. **1**, as seen from a plane indicated by the line **8-8** in FIG. **3**:

FIG. **10** a schematic top plan view of an assembled combination of the rotary knife blade, the blade housing, and the blade-blade housing bearing structure of the power operated rotary knife of FIG. **1**;

FIG. **11** is a schematic rear elevation view of the assembled combination of the rotary knife blade, blade housing, and blade-blade housing bearing structure of FIG. **10**, as seen from a plane indicated by the line **11-11** in FIG. **10**, with a blade housing plug removed from the blade housing;

FIG. **12** is a schematic side elevation view of the assembled combination of the rotary knife blade, blade housing, and blade-blade housing bearing structure of FIG. **10**, as seen from a plane indicated by the line **12-12** in FIG. **10**, with a blade housing plug removed from the blade housing;

FIG. **13** is a schematic enlarged section view of the assembled combination of the rotary knife blade, the blade housing and the blade-blade housing bearing structure of the power operated rotary knife of FIG. **1** as seen from a plane indicated by the line **13-13** in FIG. **10**;

FIG. **14** is a schematic perspective view of the elongated rolling bearing strip of the blade-blade housing bearing structure of the power operated rotary knife of FIG. **1**;

FIG. **15** is a schematic section view of the rolling bearing strip of FIG. **14** taken transverse to a longitudinal axis of the strip, as seen from a plane indicated by the line **15-15** in FIG. **14**, to show a schematic section view of an elongated separator cage of the rolling bearing strip at a position where no rolling bearing is located;

FIG. **16** is a schematic top plan view of a short portion of the rolling bearing strip of FIG. **14** taken along the longitudinal axis of the strip, as seen from a plane indicated by the line **16-16** in FIG. **14**, to show a schematic top plan view of the elongated separator cage of the rolling bearing strip at a position where a rolling bearing is located;

FIG. **17** is a schematic section view of the short portion of the rolling bearing strip of FIG. **14**, as seen from a plane indicated by the line **17-17** in FIG. **14**, with the rolling bearing removed to show a schematic section view of a pocket of the elongated separator cage;

FIG. **18** is a schematic perspective view representation of a method of releasably securing the rotary knife blade to the blade housing utilizing the blade-blade housing bearing structure in the power operated rotary knife of FIG. **1**, showing alignment of the elongated rolling bearing strip with an annular passageway defined between the rotary knife blade and the blade housing;

FIG. **19** is a schematic section view representation of a method of releasably securing the rotary knife blade to the blade housing utilizing the blade-blade housing bearing structure in the power operated rotary knife of FIG. **1**, showing partial insertion of the elongated rolling bearing strip into the annular passageway between the rotary knife blade and the blade housing;

FIG. **20** is a schematic section view representation of a method of releasably securing the rotary knife blade to the blade housing utilizing the blade-blade housing bearing structure in the power operated rotary knife of FIG. **1**, showing completion of insertion of the elongated rolling bearing strip into the annular passageway between the knife blade and the blade housing;

FIG. **21** is a schematic section view representation of a method of releasably securing the rotary knife blade to the blade housing utilizing the blade-blade housing bearing structure in the power operated rotary knife of FIG. **1**, showing attachment of the blade housing plug to the blade housing after insertion of the elongated rolling bearing strip into the annular passageway between the knife blade and the blade housing;

FIG. **22** is a schematic enlarged top plan view of a portion of the annular rotary knife blade of the power operated rotary knife of FIG. **1**;

FIG. **23** is schematic enlarged bottom plan view of the portion of the annular rotary knife blade of FIG. **22**;

FIG. **24** is a schematic section view of the annular rotary knife blade of FIG. **22**, as seen from a plane indicated by the line **24-24** in FIG. **22**;

FIG. **25** is a schematic top plan view of the blade housing of the power operated rotary knife of FIG. **1**;

FIG. **26** is a schematic bottom plan view of the blade housing of FIG. **25**;

FIG. **27** is a schematic right side elevation view of the blade housing of FIG. **25**;

FIG. **28** is a schematic rear elevation view of the blade housing of FIG. **25** showing a blade housing plug opening of a mounting section of the blade housing;

FIG. **29** is a schematic section view of the blade housing of FIG. **25** as seen from a plane indicated by the line **29-29** in FIG. **25**;

FIG. **29**A is a schematic enlarged section view of a portion of the blade housing of FIG. **25** that is within a dashed circle labeled FIG. **29**A in FIG. **29**;

FIG. **30** is a schematic top plan view of the blade housing plug that is removably secured to the blade housing of FIG. **25**;

FIG. **31** is a schematic front elevation view of the blade housing plug of FIG. **30** as seen from a plane indicated by the line **31-31** in FIG. **30**;

FIG. **32** is a schematic left side elevation view of the blade housing plug of FIG. **30** as seen from a plane indicated by the line **32-32** in FIG. **30**;

FIG. **33** is a schematic front prospective view of the gearbox assembly of the power operated rotary knife of FIG. **1**;

FIG. **34** is a schematic top plan view of the gearbox assembly of FIG. **33**;

FIG. **35** is a schematic bottom plan view of the gearbox assembly of FIG. **33**;

FIG. **36** is a schematic front elevation view of the gearbox assembly of FIG. **33**;

FIG. **37** is a schematic rear elevation view of the gearbox assembly of FIG. **33**;

FIG. **38** is a schematic right side elevation view of the gearbox assembly of FIG. **33**;

FIG. **39** is a schematic longitudinal section view of the gearbox assembly of FIG. **33**, as seen from a plane indicated by the line **39-39** in FIG. **36**;

FIG. **40** is a schematic longitudinal perspective section view of the gearbox assembly of FIG. **33**, as seen from a plane indicated by the line **39-39** in FIG. **36**;

FIG. **41** is a schematic exploded perspective view of the gearbox assembly of FIG. **33**;

FIG. **42** is a schematic exploded side elevation view of the gearbox assembly of FIG. **33**;

FIG. **43** is a schematic exploded front elevation view of the gearbox assembly of FIG. **33**;

FIG. **44** is a schematic exploded top plan view of the gearbox assembly of FIG. **33**;

FIG. **45** is a schematic exploded rear perspective view of the head assembly of the power operated rotary knife of FIG. **1** showing the gearbox assembly, the frame body, and the assembled combination of the blade, blade housing and blade-blade housing bearing structure;

FIG. **46** is a schematic rear elevation view of the gearbox housing of the gearbox assembly of the power operated rotary knife of FIG. **1**;

FIG. **47** is a schematic front, bottom perspective view of the gearbox housing of FIG. **46**;

FIG. **48** is a schematic longitudinal section view of the gearbox housing of FIG. **46**, as seen from a plane indicated by the line **48-48** in FIG. **46**;

FIG. **49** is a schematic rear perspective view of the frame body of the head assembly of the power operated rotary knife of FIG. **1**;

FIG. **50** is a schematic rear elevation view of the frame body of FIG. **49**;

FIG. **51** is a schematic bottom plan view of the frame body of FIG. **49**;

FIG. **52** is a schematic front elevation view of the frame body of FIG. **49**;

FIG. **53** is a schematic exploded side elevation view of the drive mechanism of the power operated rotary knife of FIG. **1** extending from a drive motor external to the power operated rotary knife to the rotary knife blade of the power operated rotary knife;

FIG. **54** is a schematic view, partly in side elevation and partly in section, depicting use of the power operated rotary knife of FIG. **1** for trimming a layer of material from a product utilizing the "flat blade" style rotary knife blade, shown, for example, in FIG. **24**;

FIG. **55** is a schematic enlarged view, partly in side elevation and partly in section, depicting use of the power operated rotary knife of FIG. **1** for trimming a layer of material from a product utilizing the "flat blade" style rotary knife blade;

FIG. **56** is a schematic section view of a "hook blade" style rotary knife blade and associated blade housing adapted to be used in the power operated rotary knife of FIG. **1**;

FIG. **57** is a schematic section view of a "straight blade" style rotary knife blade and associated blade housing adapted to be used in the power operated rotary knife of FIG. **1**;

FIG. **58** is a is a schematic flow diagram for a method of securing and rotationally supporting the rotary knife blade with respect to the blade housing utilizing the blade-blade housing bearing structure of the power operated rotary knife of FIG. **1**

FIG. **59** is a schematic front perspective view of a second exemplary embodiment of a power operated rotary knife of the present disclosure including a head assembly, a handle assembly and a drive mechanism, the head assembly including a gearbox assembly, an annular rotary knife blade, a blade housing, and a blade-blade housing support or bearing structure;

FIG. **60** is a schematic exploded perspective view of the power operated rotary knife of FIG. **59**;

FIG. **61** is a schematic perspective view of the head assembly of the power operated rotary knife of FIG. **59**, including the gearbox assembly, the rotary knife blade, the blade housing, and the blade-blade housing support or bearing structure;

FIG. **62** is a schematic exploded perspective view of the head assembly of FIG. **61**;

FIG. **63** is a schematic top plan view of the head assembly of FIG. **61**;

FIG. **64** is a schematic bottom plan view of the head assembly of FIG. **61**;

FIG. **65** is a schematic front elevation view of the head assembly of FIG. **61**;

FIG. **66** is a schematic rear perspective view of the head assembly of FIG. **61**;

FIG. **67** is a schematic longitudinal section view of the head assembly of FIG. **61**;

FIG. **68** is a schematic exploded rear perspective view of the head assembly of FIG. **61**;

FIG. **69** is a schematic top plan view of a blade-blade housing combination of the head assembly of the power operated rotary knife of FIG. **59** including an assembled combination of the rotary knife blade, the blade housing, and the blade-blade housing bearing structure, with a blade housing plug of the blade housing removed;

FIG. **70** is a schematic exploded rear perspective view of the blade-blade housing combination of FIG. **69**;

FIG. **71** is a schematic enlarged section view of the blade-blade housing combination of FIG. **69** as seen from a plane indicated by the line **71-71** in FIG. **69**;

FIG. **72** is a schematic top plan view of the annular rotary knife blade of the power operated rotary knife of FIG. **59**;

FIG. **73** is schematic front elevation view of the annular rotary knife blade of FIG. **72**;

FIG. **74** is a schematic section view of the annular rotary knife blade of FIG. **72**, as seen from a plane indicated by the line **74-74** in FIG. **72**;

FIG. **75** is a schematic top plan view of the blade housing of the power operated rotary knife of FIG. **59**, with the blade housing plug removed;

FIG. **76** is a schematic bottom plan view of the blade housing of FIG. **75**;

FIG. **77** is a schematic right side elevation view of the blade housing of FIG. **75**;

FIG. **78** is a schematic rear elevation view of the blade housing of FIG. **75** showing a plug housing plug opening of a mounting section of the blade housing;

FIG. **79** is a schematic section view of the blade housing of FIG. **25** as seen from a plane indicated by the line **79-79** in FIG. **75**;

FIG. **80** is a schematic front perspective view of the blade housing plug that is removably secured to the blade housing of FIG. **75**;

FIG. **81** is a schematic front elevation view of the blade housing plug of FIG. **80**;

FIG. **82** is a schematic side elevation view of the blade housing plug of FIG. **80** as seen from a plane indicated by the line **82-82** in FIG. **81**;

FIG. **83** is a schematic front, bottom perspective view of a gearbox housing of the gearbox assembly of the power operated rotary knife of FIG. **59**;

FIG. **84** is a schematic rear, top perspective view of the gearbox housing of FIG. **83**;

FIG. **85** is a schematic top plan view of the gearbox housing of FIG. **83**;

FIG. **86** is a schematic bottom plan view of the gearbox housing of FIG. **83**;

FIG. **87** is a schematic front elevation view of the gearbox housing of FIG. **83**;

FIG. **88** is a schematic right side elevation view of the gearbox housing of FIG. **83**;

FIG. **89** is a schematic longitudinal section view of the gearbox housing of FIG. **83**, as seen from a plane indicated by the line **89-89** in FIG. **85**;

FIG. **90** is a schematic rear, bottom perspective view of the frame body and frame body bottom cover of the head assembly of the power operated rotary knife of FIG. **59**;

FIG. **91** is a schematic top plan view of the frame body of FIG. **90**;

FIG. **92** is a schematic bottom plan view of the frame body of FIG. **90**;

FIG. **93** is a schematic rear elevation view of the frame body of FIG. **90**;

FIG. **94** is a schematic top plan view of the frame body bottom cover of FIG. **90**;

FIG. **95** is a schematic bottom plan view of the frame body bottom cover of FIG. **90**;

FIG. **96** is a schematic section view of the frame body bottom cover of FIG. **90** as seen from a plane indicated by the line **96-96** in FIG. **94**;

FIG. **97** is a schematic side elevation view of a handle spacer ring of the handle assembly of the power operated rotary knife of FIG. **59**;

FIG. **98** is a schematic longitudinal section view the handle spacer ring of FIG. **97**;

FIG. **99** is a schematic front elevation view of a thrust sleeve bushing of a pinion gear bearing support assembly of the gearbox assembly of the power operated rotary knife of FIG. **59**;

FIG. **100** is a schematic longitudinal section view the thrust sleeve bushing of FIG. **99**;

FIG. **101** is a schematic front perspective view of a third exemplary embodiment of a power operated rotary knife of the present disclosure including a head assembly, a handle assembly and a drive mechanism, the head assembly including a gearbox assembly, an annular rotary knife blade, a blade housing, and a blade-blade housing support or bearing structure;

FIG. **102** is a schematic exploded perspective view of the power operated rotary knife of FIG. **101**;

FIG. **103** is a schematic top plan view of the power operated rotary knife of FIG. **101**;

FIG. **104** is a schematic bottom plan view of the power operated rotary knife of FIG. **101**;

FIG. **105** is a schematic right side elevation view of the power operated rotary knife of FIG. **101**;

FIG. **106** is a schematic front elevation view of the power operated rotary knife of FIG. **101**;

FIG. **107** is a schematic rear elevation view of the power operated rotary knife of FIG. **101**;

FIG. **108** is a schematic longitudinal section view of the power operated rotary knife of FIG. **101** as seen from a plane indicated by the line **108-108** in FIG. **103**;

FIG. **108**A is a schematic enlarged section view of a portion of the head assembly of the power operated rotary knife of FIG. **101** that is within a dashed circle labeled FIG. **108**A in FIG. **108**;

FIG. **109** is a schematic perspective longitudinal section view of the power operated rotary knife of FIG. **101** as seen from a plane indicated by the line **108-108** in FIG. **103**;

FIG. **110** is a schematic longitudinal section view of the power operated rotary knife of FIG. **101** as seen from a plane indicated by the line **110-110** in FIG. **105**;

FIG. **111** is a schematic perspective longitudinal section view of the power operated rotary knife of FIG. **101** as seen from a plane indicated by the line **110-110** in FIG. **105**;

FIG. **112** is a schematic longitudinal section view of the power operated rotary knife of FIG. **101** as seen from a plane indicated by the line **110-112** in FIG. **105**;

FIG. **113** is a schematic perspective longitudinal section view of the power operated rotary knife of FIG. **101** as seen from a plane indicated by the line **110-112** in FIG. **105**;

FIG. **114** is a schematic top plan view of a blade-blade housing combination of the head assembly of the power operated rotary knife of FIG. **101** including the rotary knife blade, the blade housing, and the blade-blade housing bearing structure;

FIG. **115** is a schematic top plan view of the blade-blade housing combination of FIG. **114** with a blade housing plug of the blade housing removed from a blade housing plug opening of the blade housing;

FIG. **116** is a schematic rear elevation view of the blade-blade housing combination of FIG. **114** with a blade housing plug of the blade housing removed from the blade housing plug opening of the blade housing;

FIG. **117** is a schematic section view of the blade-blade housing combination of FIG. **114** as seen from a plane indicated by the line **117-117** in FIG. **115**;

FIG. **118** is a schematic perspective view of the rotary knife blade of the power operated rotary knife of FIG. **101**;

FIG. **119** is a schematic sectional view of the rotary knife blade of FIG. **118** as seen from a plane indicated by the line **119-119** in FIG. **118**;

FIG. **120** is a schematic perspective view of the blade housing of the power operated rotary knife of FIG. **101**;

FIG. **121** is a schematic section view of the blade housing of FIG. **120** as seen from a plane indicated by the line **121-121** in FIG. **120**;

FIG. **122** is a schematic front perspective of the blade housing plug of the blade housing of the power operated rotary knife of FIG. **60**;

FIG. **123** is a schematic front elevation view of the power operated rotary knife of FIG. **101** with the blade-blade housing combination of the head assembly removed to show the gearbox assembly of the power operated rotary knife;

FIG. **124** is a schematic front elevation view of the gearbox assembly of the power operated rotary knife of FIG. **101**, as shown in FIG. **123**, with a pinion gear cover removed to more fully show a pinion gear and a gearbox housing of the gearbox assembly;

FIG. **125** is a schematic bottom plan view of the gearbox assembly of the power operated rotary knife of FIG. **101**;

FIG. **126** is a schematic longitudinal section view of the gearbox housing of the power operated rotary knife of FIG. **101**;

FIG. **127** is a schematic top plan view of the pinion gear cover of FIG. **103** as seen from a plane indicated by the line **105-105** in FIG. **104**;

FIG. **128** is a schematic side elevation view of the pinion gear of the gearbox assembly of the operated rotary knife of FIG. **101**;

FIG. **129** is a schematic rear elevation view of the pinion gear of FIG. **128**;

FIG. **130** is a schematic front perspective view of a fourth exemplary embodiment of a power operated rotary knife of the present disclosure including a head assembly, a handle assembly and a drive mechanism, the head assembly including a gearbox assembly, an annular rotary knife blade, a blade housing, and a blade-blade housing support or bearing structure;

FIG. **131** is a schematic exploded perspective view of the power operated rotary knife of FIG. **130**;

FIG. **132** is a schematic exploded perspective view of a blade-blade housing combination of the head assembly of the power operated rotary knife of FIG. **130** including the rotary knife blade, the blade housing and the blade-blade housing bearing structure;

FIG. **133** is a schematic exploded perspective view of the gearbox assembly of the head assembly of the power operated rotary knife of FIG. **130** including a gearbox, a gearbox housing, a frame body and a frame body cover;

FIG. **134** is a schematic top plan view of the power operated rotary knife of FIG. **130**;

FIG. **135** is a schematic bottom plan view of the power operated rotary knife of FIG. **130**;

FIG. **136** is a schematic front elevation view of the power operated rotary knife of FIG. **130**;

FIG. **137** is a schematic rear elevation view of the power operated rotary knife of FIG. **130**;

FIG. **138** is a schematic right side elevation view of the power operated rotary knife of FIG. **130**;

FIG. **139** is a schematic section view along a longitudinal axis of the power operated rotary knife of FIG. **130** as seen from a plane indicated by the line **139-139** in FIG. **134**;

FIG. **139**A is a schematic enlarged section view of portions of the head assembly and the handle assembly shown in FIG. **139** that are within a dashed circle labeled FIG. **139**A in FIG. **139**;

FIG. **140** is a schematic top plan view of a blade-blade housing combination of the head assembly of the power operated rotary knife of FIG. **130** including the rotary knife blade, the blade housing, and the blade-blade housing bearing structure, with a blade housing plug removed from a blade housing plug opening of the blade housing;

FIG. **141** is a schematic rear elevation view of the blade-blade housing combination of FIG. **140**;

FIG. **142** is a schematic section view of the blade-blade housing combination of FIG. **140** as seen from a plane indicated by the line **142-142** in FIG. **140**;

FIG. **143** is a schematic bottom perspective view of the rotary knife blade of the power operated rotary knife of FIG. **130**;

FIG. **144** is a schematic section view of the knife blade of FIG. **143**;

FIG. **145** is a schematic right side elevation view of the blade housing and blade housing plug of the power operated rotary knife of FIG. **130**;

FIG. **146** is a schematic rear elevation view of the blade housing of FIG. **145** showing a blade housing plug opening of a mounting section of the blade housing;

FIG. **147** is a schematic section view of the blade housing of FIG. **145** looking toward the mounting section from an interior of the blade housing;

FIG. **148** is a schematic exploded front elevation view of the gearbox assembly of the power operated rotary knife of FIG. **130** with a pinion gear of the gearbox assembly removed;

FIG. **149** is a schematic right side elevation view of the gearbox assembly with the pinion gear, the frame body and a frame body bottom cover of the gearbox assembly removed;

FIG. **150** is a schematic rear elevation view of the frame body of the gearbox assembly of the power operated rotary knife of FIG. **130**;

FIG. **151** is a schematic bottom plan view of the frame body of FIG. **150**;

FIG. **152** is a top plan view of a frame body bottom cover of the head assembly of the power operated rotary knife of FIG. **130**;

FIG. **153** is a schematic front, bottom perspective view of the gearbox housing of the gearbox assembly of the power operated rotary knife of FIG. **150**;

FIG. **154** is a schematic rear, top perspective view of the gearbox housing of FIG. **153**;

FIG. **155** is a schematic front perspective view of a fifth exemplary embodiment of a power operated rotary knife of the present disclosure including a head assembly, a handle assembly and a drive mechanism, the head assembly including a gearbox assembly, an annular rotary knife blade, a blade housing, and a blade-blade housing support or bearing structure;

FIG. **156** is a schematic exploded perspective view of the power operated rotary knife of FIG. **155**;

FIG. **157** is a schematic perspective view of the head assembly of the power operated rotary knife of FIG. **1559**, including the gearbox assembly, the rotary knife blade, the blade housing, and the blade-blade housing support or bearing structure;

FIG. **158** is a schematic exploded perspective view of the head assembly of FIG. **157**;

FIG. **159** is a schematic top plan view of the head assembly of FIG. **157**;

FIG. **160** is a schematic bottom plan view of the head assembly of FIG. **157**;

FIG. **161** is a schematic right side elevation view of the head assembly of FIG. **157**;

FIG. **162** is a schematic front elevation view of the head assembly of FIG. **157**;

FIG. **163** is a schematic rear perspective view of the head assembly of FIG. **157**;

FIG. **164** is a schematic longitudinal section view of the head assembly of FIG. **157** as seen from a plane indicated by the line **164-164** in FIG. **159**;

FIG. **165** is a schematic exploded rear perspective view of the head assembly of FIG. **157**;

FIG. **166** is a schematic front perspective view of a blade-blade housing combination of the head assembly of the power operated rotary knife of FIG. **155** including an assembled combination of the rotary knife blade, the blade housing, and the blade-blade housing bearing structure;

FIG. **167** is a schematic rear perspective view top plan view of a blade-blade housing combination of FIG. **166**;

FIG. **168** is a schematic top plan view of the blade-blade housing combination of FIG. **166**;

FIG. **169** is a schematic bottom plan view of the blade-blade housing combination of FIG. **166**;

FIG. **170** is a schematic right side elevation view of the blade-blade housing combination of FIG. **166**;

FIG. **171** is a schematic rear elevation view of the blade-blade housing combination of FIG. **166**;

FIG. **172** is a schematic rear perspective view of the blade-blade housing combination of FIG. **166** with a blade housing plug removed from the blade housing to show portions of the rotary knife blade and the blade-blade housing bearing structure;

FIG. **173** is a schematic top plan view of the blade-blade housing combination of FIG. **166** with the blade housing plug removed from the blade housing to show portions of the rotary knife blade and the blade-blade housing support structure;

FIG. **174** is a schematic exploded rear perspective view of the blade-blade housing combination of FIG. **166**;

FIG. **175** is a schematic enlarged section view of the assembled combination of the blade-blade housing combination of FIG. **166** as seen from a plane indicated by the line **175-175** in FIG. **173**;

FIG. **176** is a schematic top plan view of the annular rotary knife blade of the power operated rotary knife of FIG. **155**;

FIG. **177** is a schematic bottom plan view of the annular rotary knife blade of FIG. **176**;

FIG. **178** is schematic front elevation view of the annular rotary knife blade of FIG. **176**;

FIG. **179** is a schematic section view of the annular rotary knife blade of FIG. **176**, as seen from a plane indicated by the line **179-179** in FIG. **176**;

FIG. **180** is a schematic top plan view of the blade housing of the power operated rotary knife of FIG. **155**, with the blade housing plug removed;

FIG. **181** is a schematic bottom plan view of the blade housing of FIG. **180**;

FIG. **182** is a schematic right side elevation view of the blade housing of FIG. **180**;

FIG. **183** is a schematic rear elevation view of the blade housing of FIG. **180** showing the mounting section of the blade housing,

FIG. **184** is a schematic section view of the blade housing of FIG. **180** looking toward the mounting section from an interior of the blade housing, as seen from a plane indicated by the line **184-184** in FIG. **180**;

FIG. **185** is a schematic enlarged section view of a portion of the blade housing of FIG. **180** that is within a dashed circle labeled FIG. **185** in FIG. **184**;

FIG. **186** is a schematic that is removably secured to the blade housing of FIG. **180**;

FIG. **187** is a schematic front elevation view of the blade housing plug of FIG. **186**;

FIG. **188** is a schematic bottom plan view of the blade housing plug of FIG. **186**;

FIG. **189** is a schematic side elevation view of the blade housing plug of FIG. **186** as seen from a plane indicated by the line **189-189** in FIG. **187**;

FIG. **190** is a schematic front perspective view of the gearbox assembly of the power operated rotary knife of FIG. **155**, including a gearbox housing and a gear train, with a gearbox housing cover removed;

FIG. **191** is a schematic front elevation view of the gearbox assembly of FIG. **190**;

FIG. **192** with a schematic rear elevation view of the gearbox assembly of FIG. **190**;

FIG. **193** is a schematic right side elevation view of the gearbox assembly of FIG. **190**;

FIG. **194** is a schematic top elevation view of the gearbox assembly of FIG. **190**;

FIG. **195** is a schematic bottom elevation view of the gearbox assembly of FIG. **190**;

FIG. **196** is a schematic front perspective section view of the gearbox assembly of FIG. **190**, as seen from a plane indicated by the line **196-196** in FIG. **194**;

FIG. **197** is a schematic longitudinal perspective view of the gearbox assembly of FIG. **190**, as seen from a plane indicated by the line **196-196** in FIG. **194**;

FIG. **198** is a schematic front, bottom perspective view of a gearbox housing of the gearbox assembly of the power operated rotary knife of FIG. **155**;

FIG. **199** is a schematic rear, top perspective view of the gearbox housing of FIG. **198**;

FIG. **200** is a schematic top plan view of the gearbox housing of FIG. **198**;

FIG. **201** is a schematic bottom plan view of the gearbox housing of FIG. **198**;

FIG. **202** is a schematic front elevation view of the gearbox housing of FIG. **198**;

FIG. **203** is a schematic right side elevation view of the gearbox housing of FIG. **198**;

FIG. **204** is a schematic longitudinal section view of the gearbox housing of FIG. **198**, as seen from a plane indicated by the line **204-204** in FIG. **200**;

FIG. **205** is a schematic rear, bottom perspective view of the frame body and frame body bottom cover of the head assembly of the power operated rotary knife of FIG. **155**;

FIG. **206** is a schematic top plan view of the frame body of FIG. **205**;

FIG. **207** is a schematic bottom plan view of the frame body of FIG. **205**;

FIG. **208** is a schematic rear elevation view of the frame body of FIG. **205**;

FIG. **209** is a schematic top plan view of the frame body bottom cover of FIG. **205**;

FIG. **210** is a schematic bottom plan view of the frame body bottom cover of FIG. **205**;

FIG. **211** is a schematic section view of the frame body bottom cover of FIG. **205** as seen from a plane indicated by the line **211-211** in FIG. **209**;

FIG. **212** is a schematic front elevation view of a sleeve bushing of a pinion gear bearing support assembly of the gearbox assembly of the power operated rotary knife of FIG. **155**;

FIG. **213** is a schematic top plan view of the sleeve bushing of FIG. **212**; and

FIG. **214** is a schematic longitudinal section view the sleeve bushing of FIG. **212**, as seen from a plane indicated by the line **214-214** in FIG. **213**.

DETAILED DESCRIPTION

First Exemplary Embodiment—Power Operated Rotary Knife 100

Overview

Designers of power operated rotary knives are constantly challenged to improve the design of such knives with respect to multiple objectives. For example, there is a desire for increasing the rotational speed of the rotary knife blade of a power operated rotary knife. Generally, increasing blade rotational speed reduces operator effort required for cutting and trimming operations. There is also a desire for reducing the heat generated during operation of the power operated rotary knife. One source of generated heat is the blade-blade housing bearing interface, that is, heat generated at the bearing interface between the rotating knife blade and the stationary blade housing. Reducing generated heat during power operated rotary knife operation will tend to increase the useful life of various knife components. Additionally, reducing generated heat during knife operation will tend to reduce undesirable "cooking" of the product being cut or trimmed. If sufficient heat is generated in the bearing region of the rotary knife blade and blade housing, dislodged pieces or fragments of a product being cut or trimmed (e.g., small pieces or fragments of fat, gristle or meat dislodged during a trimming or cutting operations) in proximity to the bearing region may become so hot that the pieces "cook". The cooked materials tend to gum up the blade and blade housing bearing region resulting in even more undesirable heating.

There is further a desire for reducing the vibration of a power operated rotary knife during operation for purposes of improved operator ergonomics and, consequently, improved operator productivity. There is also a desire for increasing the useful life of components of a power operated rotary knife. Areas of potential improvement include the design of the rotary knife blade, the blade housing, the blade-blade housing bearing interface or bearing structure that supports the knife blade for rotation in the blade housing, and the gearing that rotatably drives the rotary knife blade in the blade housing.

Many conventional power operated rotary knives include a so-called split ring, annular blade housing. A split ring or split annular blade housing is one that includes a split through a diameter of the blade housing. The split allows for expansion of a circumference of the blade housing for purposes of removing a rotary knife blade that needs to be sharpened or is at the end of its useful life and inserting a new rotary knife blade. A split ring blade housing has several inherent disadvantages. Because of the split, a split ring blade housing is weaker than a blade housing without a split. Further, the split, which defines a discontinuity along the rotational path of the knife blade, is often a collection point for fragments of meat, fat, gristle and/or bones that are created during a cutting or trimming operation. Accumulation of such fragment or debris in the region of the split may generate heat and/or potentially result in increased vibration of the power operated rotary knife, both of which are undesirable results.

Additionally, a split ring blade housing requires operator adjustment of the blade housing circumference as the rotary knife blade wears. Given the large loading forces applied to the blade when cutting and trimming meat, wear will occur between the bearing structure of the blade and the corresponding bearing structure of the blade housing that support the blade for rotation within the blade housing. In some power operated rotary knives, the blade-blade housing bearing structure includes a portion of a radial outer surface of the rotary knife blade which serves as a bearing structure of the blade and a portion of a radial inner surface of the blade housing which serves as the corresponding or mating bearing structure of the blade housing. In such power operated rotary knifes, the outer radial surface of the blade and the corresponding radial inner surface of the blade housing will wear over time resulting in a gradual loosening of the rotary knife blade within the blade housing.

In certain power operated rotary knives, the blade-blade housing bearing structure comprises an inwardly extending bead of the blade housing that extends into a bearing race formed in a radial outer surface of the rotary knife blade to support the blade for rotation in the blade housing. Again, the bearing race of the blade and the bearing bead of the blade housing will wear over time resulting in looseness of the rotary knife blade within the blade housing. As the rotary knife blade becomes looser within the blade housing, the power operated rotary knife will typically experience increased vibration. An inexperienced operator may simply accept the increased vibration of the power operated rotary knife as a necessary part of using such a knife and will reduce his or her productivity by cutting or trimming at a slower pace, turning the knife off, taking additional time between cuts, etc.

An experienced operator may recognize that a potential solution to the problem of increased vibration is to adjust, that is, reduce the blade housing circumference, i.e., reduce the effective blade housing diameter, to account for the blade and blade housing bearing interface wear. Such an adjustment of the blade housing circumference is a trial and error technique that requires the operator to find a suitable operating clearance. Operating clearance can be viewed as striking a proper balance between providing sufficient blade-blade housing bearing clearance, that is, having the bearing diameter of the blade housing sufficiently larger than the corresponding mating bearing diameter of the knife blade such that the knife blade freely rotates in the blade housing while at the same time not having too much clearance that would cause the knife blade to have excessive play and/or vibrate in the blade housing.

However, even for an experience operator, adjustment of the blade housing circumference may be problematic. If the operator fails to appropriately adjust the blade housing circumference, i.e., find a suitable operating clearance, the power operated rotary knife may not function properly. If the operator's adjustment leads to insufficient operating clearance, the knife blade will not rotate freely in the blade housing, that is, the knife blade will tend to bind in the blade housing thereby generating heat and tending to increase the wear of the rotary knife blade, blade housing and drive gear components, all undesirable results. Depending on the degree of binding, the rotary knife blade may lock-up within the housing. On the other hand if the operator adjusts the blade housing circumference such that the operating clearance is too large, the knife blade will be loose in the blade housing. This may result in excessive movement of the knife blade within the blade housing and attendant problems of excessive vibration of the power operated rotary knife during operation.

Further, even if the operator is successful in adjusting the blade housing to an acceptable circumference, adjustment of the blade housing circumference necessarily requires the operator to cease cutting/trimming operations with the power operated rotary knife during the trial and error adjustment process. The adjustment process results in downtime and lost operator productivity. Finally, since wear of the rotary knife blade and blade housing bearing interface is ongoing as the power operated rotary knife continues to be used for cutting and trimming operations, the blade housing circumference adjustment undertaken by the operator is only a temporary fix as further wear occurs.

The present disclosure relates to a power operated rotary knife that addresses many of the problems associated with conventional power operated rotary knives and objectives of power operated rotary knife design. One exemplary embodiment of a power operated rotary knife of the present disclosure is schematically shown generally at **100** in FIGS. **1-9**. The power operated rotary knife **100** comprises an elongated handle assembly **110** and a head assembly or head portion **111** removably coupled to a forward end of the handle assembly **110**. The handle assembly **110** includes a hand piece **200** that is secured to the head assembly **111** by a hand piece retaining assembly **250**.

In one exemplary embodiment, the head assembly **111** includes a continuous, generally ring-shaped or annular rotary knife blade **300**, a continuous, generally ring-shaped or annular blade housing **400**, and a blade-blade housing support or bearing structure **500**. Annular, as used herein, means generally ring-like or generally ring-shaped in configuration. Continuous annular, as used herein, means a ring-like or ring-shape configuration that is continuous about the ring or annulus, that is, the ring or annulus does not include a split extending through a diameter of the ring or annulus. The head assembly **111** further includes a gearbox assembly **112** and a frame or frame body **150** for securing the rotary knife blade **300** and the blade housing **400** to the gearbox assembly **112**.

The rotary knife blade **300** rotates in the blade housing **400** about a central axis of rotation R. In one exemplary embodiment, the rotary knife blade **300** includes a bearing surface **319** and a driven gear **328**. Both the bearing race **319** and the driven gear **328** are axially spaced from an upper end **306** of a body **302** of the blade **300** and from each other. The rotary knife blade **300** is supported for rotation in the blade housing **400** by the blade-blade housing support or bearing structure **500** of the present disclosure (best seen in FIGS. **2**A and **14**). The blade-blade housing bearing structure **500** advantageously both supports the rotary knife blade **300** for rotation with respect to the blade housing **400** and releasably secures the rotary knife blade **300** to the blade housing **400**.

In one exemplary embodiment, the blade-blade housing bearing structure **500** includes an elongated rolling bearing strip **502** (FIG. **14**) having a plurality of spaced apart rolling bearings **506** supported in a flexible separator cage **508**. The elongated rolling bearing strip **502** is disposed in an annular passageway **504** (FIG. **13**) formed between opposing bearing surfaces **319**, **459** of the rotary knife blade **300** and the blade housing **400**, respectfully. The blade-blade housing bearing structure **500** defines a plane of rotation RP (FIGS. **7** and **8**) of the rotary knife blade **300** with respect to the blade housing **400**, the rotational plane RP being substantially orthogonal to the rotary knife blade central axis of rotation R.

In one exemplary embodiment, the plurality of rolling bearings **506** comprises a plurality of generally spherical ball bearings. The plurality of ball or rolling bearings **506** are in rolling contact with and bear against the opposing bearing surfaces **319**, **459** of the rotary knife blade **300** and the blade housing **400** to support the knife blade **300** for rotation with respect to the blade housing **400** and secure the knife blade **300** with respect to the blade housing **400**. The flexible separator cage **508** rotatably supports and locates the plurality of rolling bearings **506** in spaced apart relation within the annular passageway **504**. The flexible separator cage **508** does not function as a bearing structure or provide a bearing surface with respect to the rotary knife blade **300** and the blade housing **400**. The function of rotatably supporting the rotary knife blade **300** with respect to the blade housing **400** is solely provided by the rolling bearing support of the plurality of spaced apart ball bearings **506**. This rolling bearing support can be contrasted with power operated rotary knives utilizing a sliding bearing structure. For example, U.S. Pat. No. 6,769,184 to Whited, discloses a sliding bearing structure comprising a blade housing having a plurality of circumferentially spaced, radially inwardly extending bead sections that extend into and bear against a bearing race or groove of a rotary knife blade and U.S. Published Application Pub. No, US 2007/0283573 to Levsen, which discloses a sliding bearing structure comprising an annular bushing having an elongated bushing body disposed along a groove in a blade housing and in contact with opposing bearing surfaces of a rotary knife blade and the blade housing.

As can best be seen in the sectional view of FIG. **13**, the flexible separator cage **508** is configured to ride in the annular passageway **504** without substantial contact with either the knife blade **300** or the blade housing **400** or the opposing bearing surfaces **319**, **459** of the knife blade **300** and blade housing. Indeed, it would not be desired for the flexible separator cage **508** to be in contact with or in bearing engagement with either the rotary knife blade **300** or the blade housing **400** as this would resulting in undesirable sliding friction. The blade-blade housing bearing structure **500** rotatably supports the knife blade **300** with respect to the blade housing **400** via rolling bearing support provided by the plurality of ball bearings **506** of the rolling bearing strip **502** bearing against the opposing bearing surfaces **319**, **459** of the rotary knife blade **300** and the blade housing **400**.

The rotational speed of a specific rotary knife blade **300** in the power operated rotary knife **100** will depend upon the specific characteristics of a drive mechanism **600** (shown schematically in FIG. **53**) of the power operated rotary knife **100**, including an external drive motor **800**, a flexible shaft drive assembly **700**, a gear train **604**, and a diameter and gearing of the rotary knife blade **300**. Further, depending on the cutting or trimming task to be performed, different sizes and styles of rotary knife blades may be utilized in the power operated rotary knife **100** of the present disclosure. For example, rotary knife blades in various diameters are typically offered ranging in size from around 1.4 inches in diameter to over 7 inches in diameter. Selection of a blade diameter will depend on the task or tasks being performed.

Increasing the rotational speed of the rotary knife blade of a power operated rotary knife is an important objective of designers of power operated rotary knives. The rolling bearing structure of the blade-blade housing bearing structure **500** of the present disclosure results in reduced friction, less generated heat and less surface wear than would be the case with a sliding or journal bearing structure. Because of the reduced friction and heat resulting from a rolling bearing structure, the rolling blade-blade housing bearing structure **500** permits increased rotational speed of the rotary knife blade **300** compared to the sliding bearing structures disclosed or used in prior power operated rotary knives.

By way of example only and without limitation, the following table compares blade rotational speed of two exemplary power operated rotary knives of the present disclosure versus the assignee's previous versions of those same models of power operated rotary knives. Of course, it should be appreciated the blade rotational speed increase will vary by model and will be dependent upon the specific characteristics of each particular model and blade size.

Model	Approx. Blade Diameter	Approximate Blade Rotational Speed % Increase
1000/1500	5.0 inches	51% (930 RPM vs. 1,400 RPM)
620	2.0 inches	57% (1,400 RPM vs. 2,200 RPM)

There are also significant advantages to using the flexible separator cage **508** to support and locate the plurality of rolling bearings **506**, as opposed to, for example, using only a plurality of rolling bearings, such as ball bearings, inserted into a gap or passageway between the rotary knife blade and the blade housing. The flexible separator cage **508** facilitates insertion of and removal of, as a group, the plurality of rolling bearings **506** into and from the annular passageway **504**. That is, it is much easier to insert the rolling bearing strip **502** into the annular passageway **504**, as opposed to attempting to insert individual rolling bearings into the annular passageway **504** in a one-at-a-time, sequential order, which would be both time consuming and fraught with difficulty. This is especially true in a meat processing environment where a dropped or misplaced rolling bearing could fall into a cut or trimmed meat product. Similarly, removal of the plurality of rolling bearings **506**, as a group, via removal of the rolling bearing strip **502** is much easier and less prone to dropping or losing rolling bearings than individually removing rolling bearings from the annular passageway **504**.

Additionally, from the viewpoints of friction, bearing support and cost, utilizing the plurality of rolling bearings **506** supported in a predetermined, spaced apart relationship by the flexible separator cage **508**, is more efficient and effective than utilizing a plurality of rolling bearings disposed loosely in a gap or passageway between the rotary knife blade and the blade housing. For example, the separator cage **508** allows for the plurality of rolling bearings **506** to be appropriately spaced to provide sufficient rolling bearing support to the rotary knife blade **300** given the application and characteristics of the product or material to be cut or trimmed with the power operated rotary knife **100**, while at the same time, avoids the necessity of having more rolling bearings than required for proper bearing support of the rotary knife blade **500** and the application being performed with the power operated rotary knife **100**.

For example, if the individual rolling bearings are tightly packed in a one-adjacent-the-next relationship in the annular passageway **504**, more rolling bearings than needed for most applications would be provided, thereby unnecessarily increasing cost. Further, having more rolling bearings than needed would also increase total friction because of the friction between each pair of adjacent, in-contact, rolling bearings. If, on the other hand, the individual rolling bearings are loosely packed in the annular passageway **504**, there is no control over the spacing between adjacent rolling bearings. Thus, there may be instances where a large gap or space may occur between two adjacent rolling bearings resulting in insufficient bearing support in a particular region of the annular passageway **504**, given the cutting forces being applied to the rotary knife blade **300** during a specific cutting or trimming application or operation.

As can best be seen in FIG. **2**, an assembled combination **550** of the rotary knife blade **300**, the blade housing **400** and blade-blade housing bearing structure **500** is releasably secured as a unitary structure to the gearbox assembly **112** by the frame body **150** thereby completing the head assembly **111**. For brevity, the assembled combination **550** of the rotary knife blade **300**, the blade housing **400** and blade-blade housing bearing structure **500** will hereinafter be referred to as the blade-blade housing combination **550**. The handle assembly **110** is releasably secured to the head assembly **111** thereby completing the power operated rotary knife **100**. As used herein, a front or distal end of the power operated rotary knife **100** is an end of the knife **100** that includes the blade-blade housing combination **550** (as seen in FIG. **1**), while a rear or proximal end of the power operated rotary knife **100** is an end of the knife **100** that includes the handle assembly **110**, and specifically, an enlarged end **260** of an elongated central core **252** of the hand piece retaining assembly **250** (as seen in FIG. **1**).

The head assembly **111** includes the frame **150** and the gearbox assembly **112**. As is best seen in FIGS. **2**C and **33**, the gearbox assembly **112** includes a gearbox housing **113** and a gearbox **602**. The gearbox **602** is supported by the gearbox housing **113**. The gearbox **602** includes the gear train **604** (FIG. **41**). The gear train **604** includes, in one exemplary embodiment, a pinion gear **610** and a drive gear **650**. The gearbox **602** includes the gear train **604**, along with a bearing support assembly **630** that rotatably supports the pinion gear **610** and a bearing support assembly **660** that rotatably supports the drive gear **650**.

The drive gear **650** is a double gear that includes a first bevel gear **652** and a second spur gear **654**, disposed in a stacked relationship, about an axis of rotation DGR (FIG. **8**A) of the drive gear **650**. The drive gear axis of rotation DRG is substantially parallel to the rotary knife blade axis of rotation R. The drive gear first bevel gear **652** meshes with the pinion gear **610** to rotatably drive the drive gear **650** about the drive gear axis of rotation DGR. The second spur gear **654** of the drive gear engages the driven gear **328** of the rotary knife blade **300**, forming an involute gear drive, to rotate the knife blade **300** about the blade axis of rotation R.

The gear train **604** is part of the drive mechanism **600** (shown schematically in FIG. **53**), some of which is external to the power operated rotary knife **100**, that provides motive power to rotate the rotary knife blade **300** with respect to the blade housing **400**. The drive mechanism **600** includes the external drive motor **800** and the flexible shaft drive assembly **700**, which is releasably secured to the handle assembly **110** by a drive shaft latching assembly **275** (FIG. **2**B). The gear train **604** of the power operated rotary knife **100** transmits rotational power from a rotating drive shaft **702** of the flexible shaft drive assembly **700**, through the pinion and drive gears **610**, **650**, to rotate the rotary knife blade **300** with respect to the blade housing **400**.

The frame body **150** (FIGS. **2**C and **49**) of the head assembly **111** includes an arcuate mounting pedestal **152** at a front or forward end of the frame body **150**. The arcuate mounting pedestal **152** defines a seating region **152***a* for a mounting section **402** of the blade housing **400** such that the blade-blade housing combination **550** may be releasably affixed to the frame body **150**. The frame body **150** also defines a cavity or opening **155** (FIG. **49**) that slidably receives the gearbox housing **113**, as the gearbox housing is moved in a forward direction FW (FIGS. **3**, **7** and **45**) along the longitudinal axis LA in the direction of the frame body **150**. When the gearbox housing **113** is fully inserted into the frame cavity **155** and secured to the frame body **150** by a pair of threaded fasteners **192**, as is shown schematically in FIG. **53**, the drive gear **650** of the gear train **604** engages and meshes with the driven gear **328** of the rotary knife blade **300** to rotate the blade **300** about its axis of rotation R.

The frame body **150** releasably couples the blade-blade housing combination **550** to the gearbox housing **113** to form the head assembly **111** of the power operated rotary knife **100**. The hand piece **200** of the handle assembly **110** is secured or mounted to the head assembly **111** by the hand piece retaining assembly **250** (FIG. **2**B) to complete the power operated rotary knife **100**. The elongated central core **252** of the hand piece retaining assembly **250** extends through a central throughbore **202** of the hand piece **200** and threads into the gearbox housing **113** to secure the hand piece **200** to the gearbox housing **113**.

The handle assembly **110** (FIG. **2**B) extends along a longitudinal axis LA (FIGS. **3**, **7** and **8**) that is substantially orthogonal to the central axis of rotation R of the rotary knife blade **300**. The hand piece **200** includes an inner surface **201** that defines the central throughbore **202**, which extends along the handle assembly longitudinal axis LA. The hand piece **200** includes a contoured outer handle or outer gripping surface **204** that is grasped by an operator to appropriately manipulate the power operated rotary knife **100** for trimming and cutting operations.

In one exemplary embodiment, the hand piece **200** and the elongated central core **252** of the handle assembly **110** may be fabricated of plastic or other material or materials known to have comparable properties and may be formed by molding and/or machining. The hand piece **200**, for example, may be fabricated of two over molded plastic layers, an inner layer comprising a hard plastic material and an outer layer or gripping surface comprised of a softer, resilient plastic material that is more pliable and easier to grip for the operator. The gearbox housing **113** and the frame body **150** of the head assembly **111** may be fabricated of aluminum or stainless steel or other material or materials known to have comparable properties and may be formed/shaped by casting and/or machining. The blade and blade housing **400** may be fabricated of a hardenable grade of alloy steel or a hardenable grade of stainless steel, or other material or materials known to have comparable properties and may be formed/shaped by machining, forming, casting, forging, extrusion, metal injection molding, and/or electrical discharge machining or another suitable process or combination of processes.

Rotary Knife Blade **300**

In one exemplary embodiment and as best seen in FIGS. **2**A and **22-24**, the rotary knife blade **300** of the power operated rotary knife **100** is a one-piece, continuous annular structure. As can best be seen in FIG. **24**, the rotary knife blade **300** includes the body **302** and a blade section **304** extending axially from the body **302**. The knife blade body **302** includes an upper end **306** and a lower end **308** spaced axially from the upper end **306**. The body **302** of the rotary knife blade **300** further includes an inner wall **310** and an outer wall **312** spaced radially apart from the inner wall **310**. An upper, substantially vertical portion **340** of the body outer wall **312** defines the knife blade bearing surface **319**. In one exemplary embodiment of the power operated rotary knife **100** and as best seen in FIGS. **13** and **24**, the knife blade bearing surface **319** comprises the bearing race **320** that extends radially inwardly into the outer wall **312**. In one exemplary embodiment, the knife blade bearing race **320** defines a generally concave bearing surface, and, more specifically, a generally arcuate bearing face **322** in a central portion **324** of the bearing race **320**. As can be seen in FIG. **24**, the knife blade bearing race **320** is axially spaced from an upper end **306** of the knife blade body **302**. Specifically, a section **341** of the vertical portion **340** of the body outer wall **312** extends between the knife blade bearing race **320** and the upper end **306** of the knife blade body **302**. Stated another way, the knife blade body outer wall **213** includes the vertical section **341** which separates the knife blade bearing race **320** from the upper end **306** of the knife blade body **302**. When viewed in three dimensions, the vertical section **341** defines a uniform diameter, cylindrical portion of the knife blade body outer wall **312** which separates the knife blade bearing race **320** from the upper end **306** of the knife blade body **302**.

The outer wall **312** of the body **302** of the rotary knife blade **300** also defines the driven gear **328**. The driven gear **328** comprises a set of spur gear teeth **330** extending radially outwardly in a stepped portion **331** of the outer wall **312**. The blade gear **330** is a spur gear which means that it is a cylindrical gear with a set of gear teeth **328** that are parallel to the axis of the gear, i.e., parallel to the axis of rotation R of the rotary knife blade **300** and a profile of each gear tooth of the set of gear teeth **328** includes a tip or radially outer surface **330***a* (FIG. **13**) and a root or radially inner surface **330***b*. The root **330***b* of the gear tooth is sometimes referred to as a bottom land, while the tip **330***a* of the gear tooth is sometimes referred to as a top land. The root **330***b* is radially closer to the axis of rotation R of the blade **300**, the root **330***a* and the tip **330***a* are radially spaced apart by a working depth plus clearance of a gear tooth of the set of gear teeth **330**. The driven gear **328** of the rotary knife blade **300** is axially spaced from and disposed below the bearing race **320**, that is, closer to the second lower end **308** of the knife blade body **302**. The knife blade body outer wall **312** includes the vertical portion **340** which separates the set of gear teeth **330** from the upper end **306** of the knife blade body **302**. When viewed in three dimensions, the vertical portion **340** defines a uniform diameter, cylindrical portion of the knife blade body outer wall **213** which separates the knife blade bearing race **320** from the upper end **306** of the knife blade body **302**. The driven gear **328**, in one exemplary embodiment, defines a plurality of involute spur gear teeth **332**.

The set of spur gear teeth **330** of the knife blade driven gear **328** are axially spaced from both the upper end **306** of the body **302** and the lower end **308** of the body **302** and are axially spaced from the arcuate bearing race **320** of the body **302**. Additionally, the driven gear **328** is also offset radially inwardly with respect to the upper vertical portion **340** of the body outer wall **312** that defines the blade bearing race **320**. Specifically, the set of spur gear teeth **330** are disposed radially inwardly of an outermost extent **343** of the outer wall **312** of the knife blade body **302**. As can be seen in FIGS. **13** and **24**, the upper vertical portion **340** of the body outer wall **312** defines the outermost extent **343** of the outer wall **312**. Accordingly, the upper vertical portion **340** of the outer wall **312** extends radially outwardly over the set of gear teeth **330** and form a gear tooth cap **349**. The gear tooth cap **349** is axially spaced from and overlies the set of gear teeth **330** and functions to further protect the set of gear teeth **330**.

This configuration of the rotary knife blade **300**, wherein the set of gear teeth **330** are both axially spaced from the upper end **306** of the knife blade body **302** and inwardly offset from the outermost extent **343** of the blade body outer wall **312** is sometimes referred to as a "blind gear tooth" configuration. Advantageously, the driven gear **328** of the rotary knife blade **300** of the present disclosure is in a relatively protected position with respect to the knife blade body **302**. That is, the driven gear **328** is in a position on the knife blade body **302** where there is less likely to be damage to the set of gear teeth **330** during handling of the rotary knife blade **300** and, during operation of the power operated rotary knife **100**, there is less ingress of debris, such as small pieces fat, meat, bone and gristle generated during cutting and trimming operations, into the gear teeth region.

Conceptually, the respective gear tips or radially outer surfaces **330***a* of the set of gear teeth **330**, when the knife blade **300** is rotated, can be viewed as forming a first imaginary cylinder **336** (shown schematically in FIG. **24**). Similarly, the respective roots or radially inner surfaces **330***b* of the set of gear teeth **330**, when the knife blade **300** is rotated, can be viewed as forming a second imaginary cylinder **337**. A short radially or horizontally extending portion **342** of the outer wall **312** of the blade body **302** extends between the radially outer surfaces **330***a* of the driven gear **328** and the vertical upper portion **340** of the outer wall **312** of the blade body. A second substantially vertical lower portion **344** of the outer wall **312** of the blade body **302** extends between a bottom surface **345** of the driven gear **328** and the lower end **308** of the blade body. As can be seen in FIG. **24**, the vertical lower portion **344** of the knife blade body **302** results in a radially extending projection **348** adjacent the lower end **308** of the blade body **302**.

Axial spacing of the drive gear **328** from the upper end **306** of the knife blade body **302** advantageously protects the set of gear teeth **330** from damage that they would otherwise be exposed to if, as is the case with conventional rotary knife blades, the set of gear teeth **330** were positioned at the upper end **306** of the blade body **302** of the rotary knife blade **300**. Additionally, debris is generated by the power operated rotary knife **100** during the cutting/trimming operations. Generated debris include pieces or fragments of bone, gristle, meat and/or fat that are dislodged or broken off from the product being cut or trimmed by the power operated rotary knife **100**. Debris may also include foreign material, such as dirt, dust and the like, on or near a cutting region of the product being cut or trimmed. Advantageously, spacing the set of gear teeth **330** from both axial ends **306**, **308** of the knife blade body **302**, impedes or mitigates the migration of such debris into the region of the knife blade driven gear **328**. Debris in the region of knife blade driven gear **328** may cause or contribute to a number of problems including blade vibration, premature wear of the driven gear **328** or the mating drive gear **650**, and “cooking” of the debris.

Similar advantages exist with respect to axially spacing the blade bearing race **320** from the upper and lower ends **306**, **308** of the blade body **302**. As will be explained below, the rotary knife blade body **302** and the blade housing **400** are configured to provide radially extending projections or caps which provide a type of labyrinth seal to inhibit entry of debris into the regions of the knife blade driven gear **328** and the blade-blade housing bearing structure **500**. These labyrinth seal structures are facilitated by the axial spacing of the knife blade drive gear **328** and the blade bearing race **320** from the upper and lower ends **306**, **308** of the blade body **302** of the rotary knife blade **300**.

As can best be seen in FIG. **24**, in the rotary knife blade **300**, the second end **308** of the knife blade body **302** transitions radially inwardly between the body **302** and the blade section **304**. The second end **308** of the body **302** is defined by a radially inwardly extending step or shoulder **308***a*. The blade section **304** extends from the second end **308** of the body **302** and includes a blade cutting edge **350** at an inner, lower end **352** of the blade section **304**. As can be seen, the blade section **304** includes an inner wall **354** and a radially spaced apart outer wall **356**. The inner and outer walls **354**, **356** are substantially parallel. A bridging portion **358** at the forward end of the rotary knife blade **300** extends between the inner and outer walls **354**, **356** and forms the cutting edge **350** at the intersection of the bridging portion **358** and the inner wall **354**. Depending on the specific configuration of the blade section **304**, the bridging portion **358** may extend generally radially or horizontally between the inner and outer walls **354**, **356** or may taper at an angle between the inner and outer walls **354**, **356**.

The rotary knife blade body inner wall **310** and the blade section inner wall **354** together form a substantially continuous knife blade inner wall **360** that extends from the upper end **306** to the cutting edge **350**. As can be seen in FIG. **24**, there is a slightly inwardly protruding “humpback” region **346** of the inner wall **310** of the blade body **302** in the region of the bearing race **320**. The protruding region **346** provides for an increased width or thickness of the blade body **302** in the region where the bearing race **320** extends radially inwardly into the blade body outer wall **312**. The knife blade inner wall **360** is generally frustoconical in shape, converging in a downward direction (labeled DW in FIG. **24**), that is, in a direction proceeding away from the driven gear **328** and toward the cutting edge **350**. The knife blade inner wall **360** defines a cutting opening CO (FIGS. **1** and **54**) of the power operated rotary knife **100**, that is, the opening defined by the rotary knife blade **300** that cut material, such as a cut layer CL1 (FIG. **54**) passes through, as the power operated rotary knife **100** trims or cut a product P.

Blade Housing **400**

In one exemplary embodiment and as best seen in FIGS. **25-29**, the blade housing **400** of the power operated rotary knife **100** is a one-piece, continuous annular structure. The blade housing **400** includes the mounting section **402** and a blade support section **450**. The blade housing **400** is continuous about its perimeter, that is, unlike prior split-ring annular blade housings, the blade housing **400** of the present disclosure has no split along a diameter of the housing to allow for expansion of the blade housing circumference. The blade-blade housing bearing or support structure **500** of the present disclosure secures the rotary knife blade **300** to the blade housing **400**. Accordingly, removal of the knife blade **300** from the blade housing **400** is accomplished by removing a portion of the blade-blade housing structure **500** from the power operated rotary knife **100**. The blade-blade housing bearing structure **500** permits use of the continuous annular blade housing **400** because there is no need to expand the blade housing circumference to remove the rotary knife blade **300** from the blade housing **400**.

The continuous annular blade housing **400** of the present disclosure provides a number of advantages over prior split-ring annular blade housings. The one-piece, continuous annular structure provides for greater strength and durability of the blade housing **400**, as compared to prior split-ring annular blade housings. In addition to greater strength and durability of the blade housing **400**, the fact that a circumference of the blade housing **400** is not adjustable eliminates need for and precludes the operator from adjusting the circumference of the blade housing **400** during operation of the power operated rotary knife **100** in an attempt to maintain proper operating clearance. This is a significant improvement over the prior split ring annular blade housings. Advantageously, the combination of the rotary knife blade **300**, the blade housing **400** and the blade-blade housing bearing structure **500** of the power operated rotary knife **100** provide for proper operating clearance of the rotary knife blade **300** with respect to the blade housing **400** over the useful life of a given rotary knife blade.

As can best be seen in FIG. **25**, in the blade housing **400**, the blade support section extends around the entire 360 degrees (360°) circumference of the blade housing **400**. The mounting section **402** extends radially outwardly from the blade support section **450** and subtends an angle of approximately 120°. Stated another way, the blade housing mounting section **402** extends approximately ⅓ of the way around the circumference of the blade housing **400**. In the region of the mounting section **402**, the mounting section **402** and the blade support section **450** overlap.

The mounting section **402** is both axially thicker and radially wider than the blade support section **450**. The blade housing mounting section **402** includes an inner wall **404** and a radially spaced apart outer wall **406** and a first upper end **408** and an axially spaced apart second lower end **410**. At forward ends **412**, **414** of the mounting section **402**, there are tapered regions **416**, **418** that transition between the upper end **408**, lower end **410** and outer wall **406** of the mounting section and the corresponding upper end, lower end and outer wall of the blade support section **450**.

The blade housing mounting section **402** includes two mounting inserts **420**, **422** (FIG. 2A) that extend between the upper and lower ends **408**, **410** of the mounting section **402**. The mounting inserts **420**, **422** define threaded openings **420***a*, **422***a*. The blade housing mounting section **402** is received in the seating region **152***a* defined by the arcuate mounting pedestal **152** of the frame body **150** and is secured to the frame body **150** by a pair of threaded fasteners **170**, **172** (FIG. **2**C). Specifically, the pair of threaded fasteners **170**, **172** extend through threaded openings **160***a*, **162***a* defined in a pair of arcuate arms **160**, **162** of the frame body **150** and thread into the threaded openings **420***a*, **422***a* of the blade housing mounting inserts **420**, **422** to releasably secure the blade housing **400** to the frame body **150** and, thereby, couple the blade housing **400** to the gearbox assembly **112** of the head assembly **111**.

The mounting section **402** further includes a gearing recess **424** (FIGS. **25** and **28**) that extends radially between the inner and outer walls **404**, **406**. The gearing recess **424** includes an upper clearance recess **426** that does not extend all the way to the inner wall and a wider lower opening **428** that extends between and through the inner and outer walls **404**, **406**. The upper clearance recess **426** provides clearance for the pinion gear **610** and the axially oriented first bevel gear **652** of the gearbox drive gear **650**. The lower opening **428** is sized to receive the radially extending second spur gear **654** of the gearbox drive gear **650** and thereby provide for the interface or meshing of the second spur gear **654** and the driven gear **328** of the rotary knife blade **300** to rotate the knife blade **300** with respect to the blade housing **400**.

The mounting section **402** of the blade housing **400** also includes a blade housing plug opening **429** extends between the inner and outer walls **404**, **406**. The blade housing plug opening **429** is generally oval-shaped in cross section and is sized to receive a blade housing plug **430** (FIGS. **30**-**32**). The blade housing plug **430** is removably secured to the blade housing **400** by two screws **432** (FIG. **2**A). The screws **432** pass through a pair of countersunk openings **434** that extend from the upper end **408** of the mounting section **402** to the lower portion **428** of the gearing recess **424** and threaded engage a pair of aligned threaded openings **438** of the blade housing plug **430**.

As can best be seen in FIG. **29**A, the blade support section **450** includes an inner wall **452** and radially spaced apart outer wall **454** and a first upper end **456** and an axially spaced second lower end **458**. The blade support section **450** extends about the entire 360° circumference of the blade housing **400**. The blade support section **450** in a region of the mounting section **402** is continuous with and forms a portion of the inner wall **404** of the mounting section **402**. As can be seen in FIG. **29**, a portion **404***a* of the inner wall **404** of the mounting section **402** of the blade housing **400** within the horizontally extending dashed lines IWBS constitutes both a part of the inner wall **404** of the mounting section **402** and a part of the of the inner wall **452** of the blade support section **450**. The dashed lines NUBS substantially correspond to an axial extent of the inner wall **452** of the blade support section **450**, that is, the lines IWBS correspond to the upper end **456** and the lower end **458** of the blade support section **450**. A substantially vertical portion **452***a* of the blade support section inner wall **452** adjacent the first upper end **456** defines the blade housing bearing surface **459**. In one exemplary embodiment of the power operated rotary knife **100** and as best seen in FIGS. **13** and **29**A, the blade housing bearing surface **459** comprises a bearing race **460** that extends radially inwardly into the inner wall **452**. The bearing race **460** is axially spaced from the upper end **456** of the blade support section **450**. In one exemplary embodiment, a central portion **462** of the blade housing bearing race **460** defines a generally concave bearing surface, and, more specifically, a generally arcuate bearing face **464**.

In one exemplary embodiment of the power operated rotary knife **100**, the knife blade bearing surface **319** is concave with respect to the outer wall **312**, that is, the knife blade bearing surface **319** extends into the outer wall **312** forming the bearing race **320**. It should be appreciated that the knife blade bearing surface **319** and/or the blade housing bearing surface **459** may have a different configuration, e.g., in an alternate embodiment, the knife blade bearing surface **319** and the blade housing bearing surface **459** could, for example, be convex with respect to their respective outer and inner walls **312**, **452**. The plurality of rolling bearings **506** of the blade-blade housing bearing structure **500** would, of course, have to be configured appropriately.

Though other geometric shapes could be used, the use of arcuate bearing faces **322**, **464** for the bearing races **320**, **460** of both the rotary knife blade **300** and the blade housing **400** is well suited for use with the power operated knife **100** of the present disclosure. Due to the unpredictable and varying load direction the plurality of ball bearing **506** and the arcuate bearing faces **322**, **464** allow the rotary knife blade **300** and blade housing **400** to be assembled in such a way to allow for running or operating clearance. This helps to maintain to the extent possible, the theoretical ideal of a single point of rolling bearing contact between a given ball bearing of the plurality of ball bearings **506** and the rotary knife blade arcuate bearing face **322** and the theoretical ideal of a single point of rolling bearing contact between a given ball bearing of the plurality of ball bearings **506** and the blade housing bearing face **464**, (It being understood, of course, that a single point of rolling bearing contact is a theoretical because deformation between a ball bearing and a bearing race necessarily causes deformation of the ball bearing and the bearing race resulting in a small region of contact as opposed to a point of contact.) Nevertheless, the arcuate bearing face configurations **322**, **464** provide for reduced frictional torque produced in the bearing region. Due to the thin cross sections of the rotary knife blade **300** and the blade housing **400** of the power operated rotary knife **100**, there is a tendency for both the inner or blade bearing race **320** and the outer or blade housing outer race **460** to flex and bend while in use. An arcuate bearing race design of slightly larger radius than the ball of the plurality of ball bearings **506** will allow the balls to move along an arc defined by the annular passageway **504** and still contact the respective bearing races **320**, **460** at respective single points thereby maintaining low friction even during bending and flexing of the rotary knife blade **300** and the blade housing **400**. The arcuate shape of the blade and blade housing bearing races **320**, **460** also helps compensate for manufacturing irregularities within the rotary knife blade **300** and the blade housing **400** and thereby helps maintain theoretical ideal of the single point of bearing contact between a ball bearing of the plurality of ball bearings **506** and the respective bearing races **320**, **460**, as discussed above, thereby reducing friction.

A radially inner wall **440** (FIGS. **2**A, **30** and **31**) of the blade housing plug **430** defines a bearing race **442** that is a portion of and is continuous with the bearing race **460** of the blade housing **400**. Like the portion **404***a* of the inner wall **404** of the mounting section **402** of the blade housing **400** within the horizontally extending dashed lines IWBS, a portion of the inner wall **440** of the blade housing plug **430** that would be within the horizontally extending dashed lines IWBS of FIG. **29** is both a part of the inner wall **440** of the blade housing plug **430** and a part of the inner wall **452** of the blade support section **450**. Thus, when the blade housing plug **430** is inserted in the blade housing plug opening **429** of the blade housing **400**, the blade housing bearing race **460** is substantially continuous about the entire 360° circumference of the blade support section **450**.

As can best be seen in FIG. **13**, when the blade is secured and supported within the blade housing **400** by the blade-blade housing support structure **500**, in order to impede the ingress of pieces of meat, bone and other debris into the driven gear **328** of the rotary knife blade **300**, a radially outwardly extending driven gear projection or cap **466** at the lower end **458** of the blade support section **450** is axially aligned with and overlies at least a portion of the bottom surface **345** of the set of gear teeth of the knife blade driven gear **328**. The driven gear projection or cap **466** defines the lower end **458** of the blade support section **450**. The driven gear cap **466** overlies or bridges a gap between the first and second imaginary cylinders **336**, **337** (FIG. **24**) formed by the driven gear **328** of the rotary knife blade **300**. As can be seen in FIG. **13**, because of the radial projection **348** of the knife blade body **302** and the driven gear cap **466**, only a small radial clearance gap exists between the radially extending end **467** of the driven gear cap **466** of the blade housing **400** and the projection vertical lower portion **344** of outer wall **312** of the knife blade body **302**. Advantageously, the combination of the knife blade radial projection **348** and the blade housing cap **466** form a type of labyrinth seal that inhibits ingress of debris into the regions of the driven gear **328** and the bearing race **320** of the rotary knife blade **300**.

As can best be seen in FIG. **13**, the blade support section inner wall **452** of the blade housing **400** includes a first radially outwardly extending ledge **470** that is located axially below the blade housing bearing race **460**. The blade support section inner wall **452** also includes a second radially outwardly extending ledge **472** that forms an upper surface of the driven gear cap portion **466** and is axially spaced below the first radially outwardly extending ledge **470**. The first and second ledges **470**, **472** provide a seating regions for the horizontally extending portion **342** of the knife blade outer wall **312** and the bottom surface **345** of the set of gear teeth **330**, respectively, to support the knife blade **300** when the knife blade **300** is positioned in the blade housing **400** from axially above and the rolling bearing strip **502** of the blade-blade housing bearing structure **500** has not been inserted into a passageway **504** (FIG. **13**) between the rotary knife blade **300** and the blade housing **400** defined by opposing arcuate bearing faces **322**, **464** of the knife blade bearing race **320** and the blade housing bearing race **460**. Of course, it should be understood that without insertion of the rolling bearing strip **502** into the passageway **504**, if the power operated rotary knife **100** were turned upside down, that is, upside down from the orientation of the power operated rotary knife **100** shown, for example, in FIG. **7**, the rotary knife blade **300** would fall out of the blade housing **400**.

As is best seen in FIGS. **25**, **27** and **29**, the right tapered region **416** (as viewed from a front of the power operated rotary knife **100**, that is, looking at the blade housing **400** from the perspective of an arrow labeled RW (designating a rearward direction) in FIG. **25**) of the blade housing mounting section **402** includes a cleaning port **480** for injecting cleaning fluid for cleaning the blade housing **400** and the knife blade **300** during a cleaning process. The cleaning port **480** includes an entry opening **481** in the outer wall **406** of the mounting section **402** and extends through to exit opening **482** in the inner wall **404** of the mounting section **402**. As can best be seen in FIG. **29**, a portion of the exit opening **482** in the mounting section inner wall is congruent with and opens into a region of the bearing race **460** of the blade housing **400**. The exit opening **482** in the mounting section inner wall **404** and radial gap G (FIG. **13**) between the blade **300** and the blade housing **400** provides fluid communication and injection of cleaning fluid into bearing race regions **320**, **460** of the knife blade **300** and blade housing **400**, respectively, and the driven gear **328** of the knife blade **300**.

Blade-Blade Housing Bearing Structure **500**

The power operated rotary knife **100** includes the blade-blade housing support or bearing structure **500** (best seen in FIGS. **2A**, **13** and **14**) that: a) secures the knife blade **300** to the blade housing **400**; b) supports the knife blade for rotation with respect to the blade housing about the rotational axis R; and c) defines the rotational plane RP of the knife blade. As noted previously, advantageously, the blade-blade housing support structure **500** of the present disclosure permits the use of a one-piece, continuous annular blade housing **400**. Additionally, the blade-blade housing bearing structure **500** provides for lower friction between the knife blade **300** and blade housing **400** compared to prior power operated rotary knife designs.

The lower friction afforded by the blade-blade housing bearing structure **500** advantageously permits the power operated rotary knife **100** of the present disclosure to be operated without the use of an additional, operator applied source of lubrication. Prior power operated rotary knives typically included a lubrication reservoir and bellows-type manual pump mechanism, which allowed the operator to inject an edible, food-grade grease from the reservoir into the blade-blade housing bearing region for the purpose of providing additional lubrication to the bearing region. When cutting or trimming a meat product, lubrication in the nature of fat/grease typically occurs as a natural by-product or result of cutting/trimming operations, that is, as the meat product is cut or trimmed the rotary knife blade cuts through fat/grease. As cutting/trimming operations continue and the rotary knife blade rotates within the blade housing, fat/grease from the meat product may migrate, among other places, into the blade-blade housing bearing region.

In the power operated rotary knife **100**, the fat/grease may migrate into the annular passageway **504** (FIG. **13**) defined by the opposing arcuate bearing faces **322**, **464** of the rotary knife blade bearing race **320** and the blade housing bearing race **460** as the knife **100** is used for meat cutting/trimming operations. However, in prior power operated rotary knives, this naturally occurring lubrication would typically be supplemented by the operator by using the pump mechanism to apply additional lubrication into the blade-blade housing region in an attempt to reduce blade-blade housing bearing friction, make the blade rotate easier, and reduce heating.

In one exemplary embodiment of the power operated rotary knife **100**, there is no reservoir of grease or manual pump mechanism to apply the grease. Elimination of the need for additional lubrication, of course, advantageously eliminates those components associated with providing lubrication (grease reservoir, pump, etc.) in prior power operated rotary knives. Elimination of components will reduce weight and/or reduce maintenance requirements associated with the lubrication components of the power operated rotary knife **100**. Lower friction between the knife blade **300** and the blade housing **400** decreases heat generated by virtue of friction between the rotary knife blade **300**, the blade-blade housing bearing structure **500** and the blade housing **400**. Reducing heat generated at the blade-blade housing bearing region has numerous benefits including mitigation of the aforementioned problem of "cooking" of displaced fragments of trimmed meat, gristle, fat, and bone that migrated into the blade-blade housing bearing region **504**. In prior power operated rotary knives, frictional contact between the blade and blade housing, under certain conditions, would generate sufficient heat to “cook” material in the blade-blade housing bearing region. The “cooked” material tended to accumulate in the blade-blade housing bearing region as a sticky build up of material, an undesirable result.

Additionally, the lower friction afforded by the blade-blade housing bearing structure **500** of the power operated rotary knife **100** has the additional advantage of potentially increasing the useful life of one or more of the knife blade **300**, the blade housing **400** and/or components of the gearbox **602**. Of course, the useful life of any component of the power operated rotary knife **100** is dependent on proper operation and proper maintenance of the power operated knife.

As can best be seen in FIGS. **14-17**, the blade-blade housing bearing structure **500** comprises an elongated rolling bearing strip **502** that is routed circumferentially through the annular passageway **504** about the axis of rotation R of the knife blade **300**. A rotary knife bearing assembly **552** (FIG. **13**) of the power operated rotary knife **100** includes the combination of the blade-blade housing bearing structure **500**, the blade housing bearing race **460**, the knife blade bearing race **320** and the annular passageway **504** defined therebetween. In an alternate exemplary embodiment, a plurality of elongated rolling bearing strips may be utilized, each similar to, but shorter in length than, the elongated bearing strip **502**. Utilizing a plurality of shorter elongated bearing strips in place of the single, longer elongated bearing strip **502** may be advantageous in that shorter elongated bearing strips are less difficult and less expensive to fabricate. If a plurality of elongated bearing strips are used, such strips would be sequentially inserted within the annular passageway **504** in head-to-tail fashion or in spaced apart relationship. The plurality of elongated bearing strips may include slightly enlarged end portions so that two adjacent bearing strips do not run together or to limit an extent of overlapping of two adjacent bearing strips.

In one exemplary embodiment, the central portion **462** of the blade housing bearing race **460** defines, in cross section, the substantially arcuate bearing face **464**. Similarly, the central portion **324** of the knife blade bearing race **320** defines, in cross section, the substantially arcuate bearing face **322**. As can best be seen in FIGS. **14-17**, the elongated rolling bearing strip **502**, in one exemplary embodiment, comprises the plurality of spaced apart rolling bearings **506** supported for rotation in the flexible separator cage **508**. In one exemplary embodiment, the flexible separator cage **508** comprises an elongated polymer strip **520**. The elongated polymer strip **520** defines a strip longitudinal axis SLA (FIG. **16**) and is generally rectangular when viewed in cross section. The strip **520** includes a first vertical axis SVA (FIG. **15**) that is orthogonal to the strip longitudinal axis SVA and a second horizontal axis SHA (FIG. **15**) orthogonal to the strip longitudinal axis SLA and the first vertical axis SVA. The strip first vertical axis SVA is substantially parallel to a first inner surface **522** and a second outer surface **524** of the strip **520**. As can be seen in FIG. **15**, the first inner surface **522** and the second outer surface **524** are generally planar and parallel. The strip second horizontal axis SHA is substantially parallel to a third top or upper surface **526** and a fourth bottom or lower surface **528** of the strip **520**.

Each of the plurality of ball bearings **506** is supported for rotation in a respective different bearing pocket **530** of the strip **520**. The bearing pockets **530** are spaced apart along the strip longitudinal axis SLA. Each of the strip bearing pockets **530** defines an opening **532** extending between the first inner surface **522** and the second outer surface **524**. Each of the plurality of bearing pockets **530** includes a pair of spaced apart support arms **534**, **536** extending into the opening **532** to contact and rotationally support a respective ball bearing of the plurality of ball bearings **506**. For each pair of support arms **534**, **536**, the support arms **534**, **536** are mirror images of each other. Each of the pairs of support arms **534**, **536** defines a pair of facing, generally arcuate bearing surfaces that rotationally support a ball bearing of the plurality of ball bearings **506**. Each of the pairs of support arms **534**, **536** includes an extending portion **538** that extends outwardly from the strip **520** beyond the first planar inner surface **522** and an extending portion **540** that extends outwardly from the strip **520** beyond the second planar outer surface **524**.

The plurality of ball bearings **506** of the elongated rolling bearing strip **502** are in rolling contact with and provide bearing support between the knife blade bearing race **320** and the blade housing bearing race **460**. At the same time, while supporting the knife blade **300** for low friction rotation with respect to the blade housing **400**, the elongated rolling bearing strip **502** also functions to secure the knife blade **300** with respect to the blade housing **400**, that is, the bearing strip **502** prevents the knife blade **300** from falling out of the blade housing **400** regardless of the orientation of the power operated rotary knife **100**.

When the rolling bearing strip **502** and, specifically, the plurality of ball bearings **506** are inserted into the passageway **504**, the plurality of ball bearings **506** support the knife blade **300** with respect to the blade housing **400**. In one exemplary embodiment, the plurality of ball bearings **506** are sized that their radii are smaller than the respective radii of the arcuate bearing surfaces **464**, **322**. In one exemplary embodiment, the radius of each of the plurality of ball bearings **506** is 1 mm. or approximately 0.039 inch, while radii of the arcuate bearing surfaces **464**, **322** are slightly larger, on the order of approximately 0.043 inch. However, it should be recognized that in other alternate embodiments, the radii of the plurality of ball bearings **506** may be equal to or larger than the radii of the arcuate bearing faces **464**, **322**. That is, the radii of the plurality of ball bearings **506** may be in a general range of between 0.02 inch and 0.07 inch, while the radii of the arcuate bearing surfaces **464**, **322** may be in a general range of between 0.03 inch and 0.06 inch. As can best be seen in FIG. **13**, when the rolling bearing strip **502** is inserted into the radial, annular gap G, the plurality of ball bearings **506** and a central portion **509***a* of the separator cage **508** are received in the annular passageway **504** defined between the opposing bearing surfaces **319**, **459** of the rotary knife blade **300** and the blade housing **400**. The annular passageway **504** comprises part of the annular gap Q between the opposing outer wall **312** of the rotary knife blade body **302** and the inner wall **452** of the blade housing blade support section **450**. In one exemplary embodiment, the annular gap G is in a range of approximately 0.04-0.05 inch and is disposed between the vertical inner wall portion **452***a* of the blade support section **450** of the blade housing **400** and the facing vertical outer wall portion **340** of the outer wall **312** of the body **302** of the knife blade **300**, adjacent or in the region of the opposing bearing surfaces **319**, **459**.

As can be seen in FIG. **13**, the annular passageway **504** is generally circular in cross section and receives the plurality of ball bearings **506** and a central portion **509***a* of the separator cage **508** of the elongated rolling bearing strip **502**. When positioned in the annular passageway **504**, the elongated rolling bearing strip **502** and, specifically, the separator cage **508** of the rolling bearing strip **502**, forms substantially a circle or a portion of a circle within the annular passageway **504** centered about an axis that is substantially congruent with the rotary knife blade axis of rotation R. As the separator cage **508** of the rolling bearing strip **502** is vertically oriented in the gap G, the cage **508** includes top and bottom portions **509***b* extending from the central portion **509***a*. As can be seen in FIG. **13**, the top and bottom portions **509***b* of the separator cage **508** extend axially slightly above and slightly below the plurality of ball bearings **506**. When positioned in the annular passageway **504**, the elongated rolling bearing strip **502** forms substantially a circle or a portion of a circle within the annular passageway **504** centered about an axis that is substantially congruent with the rotary knife blade axis of rotation R, while the separator cage **508** forms substantially a cylinder or a portion of a cylinder with the gap G centered about the rotary knife blade axis of rotation R.

As can be seen in FIG. **13**, the separator cage **508**, in cross section, is rectangular and is oriented in an upright position within the gap G, the separator cage **508** may be viewed as forming substantially a cylinder or a partial cylinder within the gap G centered about the rotary knife blade axis of rotation R. The plurality of ball bearings **506** ride within the annular passageway **504**, which is substantially circular in cross section and is centered about the blade axis of rotation R.

To minimize friction, it is not desirable for the flexible separator cage **508** to be in contact with or in bearing engagement with either the rotary knife blade **300** or the blade housing **400** as this would unnecessarily generate sliding friction. What is desired is for the rotary knife blade **300** to be solely supported with respect to the blade housing **400** via rolling bearing support provided by the plurality of ball bearings **506** of the rolling bearing strip **502** bearing against the opposing arcuate bearing faces **322**, **464** of the rotary knife blade **300** and the blade housing **400**. Accordingly, as can best be seen in the sectional view of FIG. **13**, the flexible separator cage **508** is configured to ride in the annular passageway **504** and in the annular gap G without substantial contact with either the knife blade **300** or the blade housing **400** or the opposing bearing surfaces **319**, **459** of the knife blade **300** and blade housing **400**. In one exemplary embodiment, a width of the upper and lower portions **509***b* of the separator cage **508** is on the order of 0.03 inch and, as mentioned previously, the annular gap G is on the order of 0.04-0.05 inch. Thus, when the rolling bearing strip **502** is inserted into the annular passageway **504**, a clearance of approximately 0.005-0.010 inch exists between the separator cage **508** and the facing vertical outer wall portion **340** of the outer wall **312** of the body **302** of the knife blade **300**, adjacent the opposing bearing surfaces **319**, **459**. Depending on the specific length of the separator cage **508** and the circumference of the gap G, the ends **510**, **512** of the separator cage **508** may be spaced apart slightly (as is shown in FIG. **14**), may be in contact, or may be slightly overlapping.

It should be appreciated that when the rotary knife blade **300** is rotated by the drive train **604** at a specific, desired RPM, the separator cage **508** also moves or translates in a circle along the annular gap G, although the rotational speed of the separator cage **508** within the gap G is less than the RPM of the rotary knife blade **300**. Thus, when the power operated rotary knife **100** is in operation, the elongated rolling bearing strip **502** traverses through the annular passageway **504** forming a circle about the knife blade axis of rotation R. Similarly, when the power operated rotary knife **100** is in operation, the separator cage **508**, due to its movement or translation along the annular gap G about the knife blade axis of rotation R, can be considered as forming a complete cylinder within the gap G. Additionally, when the rotary knife blade **300** is rotated, the plurality of ball bearings **506** both rotate with respect to the separator cage **506** and also move or translate along the annular passageway **504** about the knife blade axis of rotation R as the separator cage **508** moves or translates along the annular gap G. Upon complete insertion of the rolling bearing strip **502** into the gap G, the assembled blade-blade housing combination **550** (FIGS. **9** and **10**) is then ready to be secured, as a unit, to the frame body **150** of the head assembly **111**.

Rolling bearing strips of suitable configuration are manufactured by KMF of Germany and are available in the United States through International Customized Bearings, 200 Forsyth Dr., Step. E, Charlotte, N.C. 28237-5815.

Securing the Knife Blade **300** to the Blade Housing **400**

The blade-blade housing bearing structure **500** is utilized to both secure the rotary knife blade **300** to the blade housing **400** and to rotatably support the blade **300** within the blade housing **400**. To insert the elongated rolling bearing strip **502** of the blade-blade housing bearing structure **500** the passageway **504** formed between the radially aligned, opposing arcuate bearing faces **322**, **464** of the blade bearing race **320** and the blade housing bearing race **460**, the blade housing plug **430** is removed from the blade housing plug opening **429** of the blade housing **400**. Then, the rolling bearing strip **502** is routed between the knife blade **300** and the blade housing **400** into the annular gap G and through the passageway **504**. Next, the blade housing plug **430** is inserted in the blade housing plug opening **429** and the plug **430** is secured to the blade housing **400**. The blade-blade housing combination **550** then ready to be secured to the arcuate mounting pedestal **152** of the frame body **150**.

As can be seen in FIGS. **18**-**21** and in the flow diagram set forth in FIG. **58**, a method of securing the rotary knife blade **300** to the blade housing **400** for rotation with respect to the blade housing **400** about the blade axis of rotation R is shown generally at **900** in FIG. **58**. The method **900** includes the following steps. At step **902**, remove the blade housing plug **430** from the blade housing plug opening **429**. At step **904**, position the rotary knife blade **300** in blade housing **400** in an upright position such that blade **300** is supported by blade housing **400**. Specifically, the knife blade **300** is positioned in the blade housing **400** in an upright orientation such that the horizontal extending portion **342** of the outer wall **312** of the knife blade **300** and the bottom surface **345** of the knife blade set of gear teeth **330** are disposed on the respective first and second ledges **470**, **472** of the blade housing **400**. In this upright orientation, the blade housing bearing race **460** and the knife blade bearing race **320** are substantially radially aligned such that the annular passageway **504** is defined between the blade housing bearing race **460** and the knife blade bearing race **320**.

At step **906**, as is shown schematically in FIG. **18**, position the first end **510** of flexible separator cage **508** of rolling bearing strip **502** in blade housing plug opening **429** such that first end **510** is tangentially aligned with the gap G between the blade **300** and the blade housing **400** and the bearings **506** of the rolling bearing strip **502** are aligned with the annular passageway **504** between the opposing arcuate bearing faces **322**, **464** of the blade **300** and blade housing **400**. At step **908**, advance the flexible separator cage **508** tangentially with respect to the gap G such that bearings **506** of the rolling bearing strip **502** enter and move along the passageway **504**. That is, as is shown schematically in FIG. **19**, the separator cage **508** is advanced such that the separator cage **508** is effectively threaded through the passageway **504** and the gap G. The separator cage **508** is oriented in an upright position such that the cage fits into the gap G between the knife blade **300** and the blade housing **400**.

At step **910**, continue to advance the flexible separator cage **508** until first and second ends **510**, **512** of the separator cage **508** are substantially adjacent (FIG. **20**), that is, the separator cage **508** forms at least a portion of a circle within the passageway **504** and the gap G (like the circle C formed by the separator cage **508** schematically shown in FIG. **2**A). A longitudinal extent of the separator cage **508** of the elongated strip **502** along the strip longitudinal axis SLA is sufficient such that when the strip **502** is installed in the passageway **504**, the first and second ends **510**, **512** of the strip separator cage **508**, if not in contact, are slightly spaced apart as shown, for example in FIGS. **2**A and **14**. That is, the upright strip cage **508** when installed in the passageway **504** forms at least a portion of a cylinder within the passageway **504** and the gap G. At step **912** and as is shown schematically in FIG. **21**, insert the blade housing plug **430** in blade housing opening **429** and secure blade housing plug to blade housing **400** with the fasteners **432**.

As the rotary knife blade **400** is rotated by the gear train **604**, the elongated rolling bearing strip **502** will travel in a circular route or path of travel within the gap G, that is, the plurality of spaced apart ball bearings **506** will move in a circle though the annular passageway **504**. However, because the individual bearings are also rotating within the separator cage **508** as the separator cage **508** moves in a circular route in the gap G, the rotational speed or angular velocity of the separator cage **508** is significantly less than the rotation speed or angular velocity of the rotary knife blade **300** with respect to the blade housing **400**.

It should be appreciated that not all of the mating or coacting bearing surfaces of the rotary knife bearing assembly **552** including of the plurality of ball bearings **506** of the elongated rolling bearing strip **502**, the rotary knife blade bearing race **320**, the blade housing bearing race **460**, and the blade housing plug bearing race portion **446**, as described above, are in contact at any given time because there are necessarily running or operating clearances between the bearing strip rotary knife blade **300**, the blade housing **400**, and the blade housing plug **430** which allow the blade **300** to rotate relatively freely within the blade housing **400**.

These running or operating clearances cause the rotary knife blade **300** to act somewhat akin to a teeter-totter within the blade housing **400**, that is, as one region of the blade **300** is pivoted or moved upwardly within the blade housing **400** during a cutting or trimming operation, the diametrically opposite portion of the blade (180° away) is generally pivoted or moved downwardly within the blade housing. Accordingly, the specific mating bearing surfaces of the rotary blade bearing assembly **552** in contact at any specific location of the rotary knife blade **300**, the blade housing **400**, or the elongated bearing strip **502** will change and, at any given time, will be determined, at least in part, by the forces applied to the rotary knife blade **300** during use of the power operated rotary knife **100**. Thus, for any specific portion or region of a bearing surface of the rotary blade bearing assembly **552**, there may be periods of non-contact or intermittent contact with a mating bearing surface.

Removal of the rotary knife blade **300** from the blade housing **400** involves the reverse of the procedure discussed above. Namely, the blade housing plug **430** is removed from the blade housing **400**. The rotary knife blade **300** is rotated with respect to the blade housing **400** until the adjacent ends **510**, **512** of the separator cage **508** are visible within the blade housing plug opening **429**. A small instrument, such as a small screwdriver, is used to contact and direct or pry one end of the separator cage **508**, say, the first end **510** of the separator cage **508**, tangentially away from the gap G. Rotation of the rotary knife blade **300** is continued until a sufficient length of the separator cage **508** is extending tangentially away from the gap G and through the blade housing plug opening **429** such that the end **510** of the separator cage **508** may be grasped by the fingers of the operator. The separator cage **508** is then pulled from the gap G. Once the cage **508** has been completely removed from the gap G between the rotary knife blade **300** and the blade housing **400**, the blade housing **400** is turned upside down and the rotary knife blade **300** will fall out of the blade housing **400**.

Cutting Profile of Blade—Blade Housing Combination **550**

The friction or drag experienced by the operator as the power operated rotary knife **100** is manipulated by the operator to move through a product P, as schematically illustrated in FIGS. **54** and **55**, is dependent, among other things, on the cross sectional shape or configuration of the blade-blade housing combination **550** in a cutting region CR of the assembled combination **550**. As can best be seen in FIG. **3**, the cutting region CR of the blade-blade housing combination **550** is approximately 240° of the entire 360° periphery of the combination. The cutting region CR excludes the approximately 120° of the periphery of the blade-blade housing combination **550** occupied by the mounting section **402** of the blade housing **400**.

As can best be seen in FIGS. **54** and **55**, the blade-blade housing combination **550** is configured and contoured to be as smooth and continuous as practical. As can best be seen in FIG. **54**, a layer L**1** of material is cut or trimmed from a product P being processed (for example, a layer of tissue, for example, a layer of meat or fat trimmed from an animal carcass) by moving the power operated rotary knife **100** in a cutting direction CD such that the rotating knife blade **300** and blade housing **400** move along and through the product P to cut or trim the layer of material L**1**. As the power operated rotary knife **100** is moved by the operator, the blade edge **350** cuts the layer L**1** forming a cut portion CL**1** of the layer L**1**. The cut portion CL**1** moves along a cut or trimmed material path of travel PT through the cutting opening CO of the blade-blade housing combination **550** as the power operated rotary knife **100** advances through the product P.

A new outer surface layer NS (FIG. **55**) formed as the layer L**1** is cut away from the product P. The cut portion CL**1** of the layer L**1** slides along the inner wall **360** of the rotary knife blade **300**, while new outer surface layer NS slides along the respective outer walls **356**, **454** of the blade section **350** of the knife blade **300** and the blade support section **404** of the blade housing **400**.

A smooth transition between the blade section outer wall **356** of the knife blade **300** and the blade support section outer wall **454** of the blade housing **400** is provided by the short, radially extending driven gear cap portion **466** of the blade housing **400** and the radially extending shoulder **308***a* of the lower end **308** of the rotary knife blade body **302**. The close proximity of the radially extending end **467** of the driven gear cap portion **466** provides a labyrinth seal to impede ingress of foreign materials into the region of the knife blade driven gear **328** and the region of the blade-blade housing bearing structure **500**. Finally, the blade-blade housing combination **550** in the cutting region CR is shaped to extent possible to reduce drag and friction experienced by the operator when manipulating the power operated rotary knife in performing cutting or trimming operations.

Gear Train **604**

The drive mechanism **600** of the power operated rotary knife **100** includes certain components and assemblies internal to the power operated rotary knife **100** including the gear train **604** and the driven gear **328** of the rotary knife blade **300** and certain components and assemblies external to the power operated rotary knife **100** including the drive motor **800** and the flexible shaft drive assembly **700**, which is releasably coupled to the knife **100**, via the drive shaft latching assembly **275**.

Within the power operated rotary knife **100**, the drive mechanism **600** includes the gearbox **602** comprising the gear train **604**. In one exemplary embodiment, the gear train **604** includes the pinion gear **610** and the drive gear **650**. The drive gear **650**, in turn, engages the driven gear **328** of the rotary knife blade **300** to rotate the knife blade **300**. As noted previously, the gearbox drive gear **650**, in one exemplary embodiment, is a double gear that includes an upper, vertically or axially oriented bevel gear **652** and a lower, horizontally or radially oriented spur gear **654**. The drive gear upper bevel gear **652** engages and is rotatably driven by the pinion gear **610**. The drive gear lower spur gear **654** defines a plurality of drive gear teeth **656** that are mating involute gear teeth that mesh with the involute gear teeth **332** of the rotary knife blade driven gear **328** to rotate the rotary knife blade **300**. This gearing combination between the drive gear **650** and the rotary knife blade **300** defines a spur gear involute gear drive **658** (FIG. **8**A) to rotate the rotary knife blade **300**.

In the involute gear drive, the profiles of the rotary knife gear teeth **332** of the rotary knife blade **300** and the gear teeth **656** of the spur gear **654** of the drive gear **650** are involutes of a circle and contact between any pair of gear teeth occurs at a substantially single instantaneous point. Rotation of the drive gear **650** and the knife blade driven gear **328** causes the location of the contact point to move across the respective tooth surfaces. The motion across the respective gear tooth faces is a rolling type of contact, with substantially no sliding involved. The involute tooth form of rotary knife blade gear teeth **332** and the spur gear gear teeth **656** results in very little wear of the respective meshing gear teeth **332**, **656** versus a gearing structure wherein the meshing gear teeth contact with a sliding motion. The path traced by the contact point is known as the line of action. A property of the involute tooth form is that if the gears are meshed properly, the line of action is straight and passes through the pitch point of the gears. Additionally, the involute gear drive **658** is also a spur gear drive which means that an axis of rotation DGR (shown in FIGS. **8** and **8**A) of the drive gear **650** is substantially parallel to the axis of rotation R of the knife blade **300**. Such a spur drive with parallel axes of rotation DGR, R is very efficient in transmitting driving forces. The spur drive gearing arrangement of the rotary knife blade gear teeth **332** and the spur gear drive teeth **656** also advantageously contributes to reducing the wear of the meshing gears **332**, **656** compared with other more complex gearing arrangements.

The pinion gear **610** comprises an input shaft **612** and a gear head **614** that extends radially outwardly from the input shaft **612** and defines a set of bevel gear teeth **616**. The input shaft **612** extends in a rearward direction RW along the handle assembly longitudinal axis LA and includes a central opening **618** extending in a forward direction FW from a rearward end **629** (FIG. **41**) to a forward end **628** of the input shaft **612**, the central opening **618** terminating at the gear head **614**. An inner surface **620** of the input shaft **612** defines a cross-shaped female socket or fitting **622** (FIGS. **37** and **40**) which receives a mating male drive fitting **714** (FIG. **53**) of the shaft drive assembly **700** to rotate the pinion gear **610** about an axis of rotation PGR which is substantially congruent with the handle assembly longitudinal axis LA and intersects the knife blade axis of rotation R.

The pinion gear **610** is supported for rotation about the pinion gear axis of rotation PGR (FIGS. **8** and **8**A) by the bearing support assembly **630**, which, in one exemplary embodiment, includes a larger sleeve bushing **632** and a smaller sleeve bushing **640** (FIG. **42**). As can best be seen in FIG. **41**, a forward facing surface **624** of the gear head **614** of the pinion gear **610** includes a central recess **626** which is substantially circular in cross section and is centered about the pinion gear axis of rotation PGR. The pinion gear central recess **626** receives a cylindrical reward portion **642** of the smaller sleeve bushing **640**. The smaller sleeve bushing **640** functions as a thrust bearing and includes an enlarged annular head **644** provides a bearing surface for the pinion gear gear head **614** and limits axial travel of the pinion gear **610** in the forward direction FW, that is, travel of the pinion gear **610** along the pinion gear axis of rotation PGR, in the forward direction FW.

The sleeve bushing **640** is supported on a boss **158***b* (FIGS. **49** and **50**) of the frame body **150**. Specifically, the boss **158***b* extends rearwardly from an inner surface **158***a* of a forward wall **154***a* of a central cylindrical region **154** of the frame body **150**. The boss **158***b* of the frame body central cylindrical region **154** includes a flat **158***c* that interfits with a flat **648** (FIG. **2**C) formed in a central opening **646** of the sleeve bushing **640** to prevent rotation of the sleeve bushing **640** as the pinion gear **610** rotates about its axis of rotation PGR.

In one exemplary embodiment, the gear head **614** of the pinion gear **610** includes 25 bevel gear teeth and, at the forward facing surface **624**, has an outside diameter of approximately 0.84 inch (measured across the gear from the tops of the gear teeth) and a root diameter of approximately 0.72 inch (measured across a base of the teeth). The bevel gear teeth **616** taper from a larger diameter at the forward facing surface **624** to a smaller diameter in away from the forward facing surface **624**.

The larger sleeve bushing **632** of the pinion gear bearing support assembly **630** includes a central opening **634** that receives and rotatably supports the pinion gear input shaft **612**. The larger sleeve bushing **632** includes an enlarged forward head **636** and a cylindrical rearward body **637**. The cylindrical rearward body **637** of the larger sleeve bushing **632** is supported within a conforming cavity **129** (FIGS. **39** and **48**) of the inverted U-shaped forward section **118** of the gearbox housing **113**, while the enlarged forward head **636** of the sleeve bushing **632** fits within a conforming forward cavity **126** of the U-shaped forward section **118** of the gearbox housing **113**.

A flat **638** (FIG. **41**) of the enlarged forward head **636** of the larger sleeve bushing **632** interfits with a flat **128** of the U-shaped forward section **118** of the gearbox housing **113** to prevent rotation of the sleeve bushing **632** within the gearbox housing **113**. The cylindrical body **639** of the larger sleeve bushing **632** defining the central opening **634** provides radial bearing support for the pinion gear **610**. The enlarged head **636** of the sleeve bushing **632** also provides a thrust bearing surface for the rearward collar **627** of the gear head **614** to prevent axial movement of the pinion gear **610** in the rearward direction RW, that is, travel of the pinion gear **610** along the pinion gear axis of rotation PGR, in the rearward direction RW. Alternatively, instead of a pair of sleeve bushings **632**, **640**, the bearing support assembly **630** for the pinion gear **610** may comprise one or more roller or ball bearing assemblies or a combination of roller/ball bearing assemblies and sleeve bearings.

The drive gear **650**, in one exemplary embodiment, is a double gear with axially aligned gears including the first bevel gear **652** and the second spur gear **654**, both rotating about a drive gear axis of rotation DGR (FIGS. **8** and **8**A). The drive gear axis of rotation DGR is substantially orthogonal to and intersects a pinion gear axis of rotation PGR. Further, the drive gear axis of rotation DGR is substantially parallel to the knife blade axis of rotation R. The first gear **652** is a bevel gear and includes a set of bevel gear teeth **653** that mesh with the set of bevel gear teeth **616** of the gear head **614** of the pinion gear **610**. As the pinion gear **610** is rotated by the shaft drive assembly **700**, the bevel gear teeth **616** of the pinion gear **610**, in turn, engage the bevel gear teeth **653** of the first gear **652** to rotate the drive gear **650**.

The second gear **654** comprises a spur gear including a set of involute gear teeth **656**. The spur gear **654** engages and drives the driven gear **328** of the knife blade **300** to rotate the knife blade about its axis of rotation R. Because the spur gear **654** of the gearbox **602** and the driven gear **328** of the knife blade **300** have axes of rotation DGR, R that are parallel (that is, a spur gear drive) and because the gears **654**, **328** comprise an involute gear drive **658**, there is less wear of the respective gear teeth **656**, **332** than in other gear drives wherein the axes of rotation are not parallel and wherein a non-involute gear drive is used. In one exemplary embodiment, the first gear **652** includes 28 bevel gear teeth and has an outside diameter of approximately 0.92 inch and an inside diameter of approximately 0.66 inch and the second gear **654** includes 58 spur gear teeth and has an outside diameter of approximately 1.25 inches and a root diameter of approximately 1.16 inches.

The drive gear **650** is supported for rotation by the bearing support assembly **660** (FIGS. **39-43**). The bearing support assembly **660**, in one exemplary embodiment, comprises a ball bearing assembly **662** that supports the drive gear **650** for rotation about the drive gear rotational axis DGR. The drive gear bearing support assembly **660** is secured to a downwardly extending projection **142** (FIGS. **47** and **48**) of the inverted U-shaped forward section **118** of the gearbox housing **113**. As can be seen in FIG. **39**, the ball bearing assembly **662** includes a plurality of ball bearings **666** trapped between an inner race **664** and an outer race **668**. The outer race **668** is affixed to the drive gear **650** and is received in a central opening **670** of the drive gear **650**. The inner race **664** is supported by the fastener **672**. A threaded end portion of the fastener **672** and screws into a threaded opening **140** (FIGS. **41** and **47**) defined in a stem **143** of the downwardly extending projection **142** of the inverted U-shaped forward section **118** of the gearbox housing **113**. The fastener **672** secures the ball bearing assembly **662** to the gearbox housing **113**. Alternatively, instead of a ball bearing assembly, the bearing support assembly **660** may comprise one or more sleeve bearings or bushings.

Gearbox Housing **113**

As is best seen in FIGS. **2**C, and **33-44**, the gearbox assembly **112** includes the gearbox housing **113** and the gearbox **602**. As can best be seen in FIGS. **41-48**, the gearbox housing **113** includes a generally cylindrical rearward section **116** (in the rearward direction RW away from the blade housing **400**), an inverted U-shaped forward section **118** (in the forward direction FW toward the blade housing **400**) and a generally rectangular base section **120** disposed axially below the forward section **118**. The gearbox housing **113** includes the gearbox cavity or opening **114** which defines a throughbore **115** extending through the gearbox housing **113** from a rearward end **122** to a forward end **124**. The throughbore **115** extends generally along the handle assembly longitudinal axis LA. The inverted U-shaped forward section **118** and the cylindrical rearward section **116** combine to define an upper surface **130** of the gearbox housing **113**.

The gearbox housing **113** also includes a generally rectangular shaped base **120** which extends downwardly from the inverted U-shaped forward section **118**, i.e., away from the upper surface **130**. The rectangular base **120** includes a front wall **120***a* and a rear wall **120***b*, as well as a bottom wall **120***c* and an upper wall **120***d*, all of which are generally planar. As is best seen in FIGS. **47** and **48**, extending radially inwardly into the front wall **120***a* of the rectangular base **120** are first and second arcuate recesses **120***e*, **120***f*. The first arcuate recess **120***e* is an upper recess, that is, the upper recess **120***e* is adjacent a bottom portion **141** of the inverted U-shaped forward section **118** and, as best seen in FIG. **43**, is offset slightly below the upper wall **120***d* of the rectangular base **120**. The second arcuate recess **120***f* is a lower recess and extends through the bottom wall **120***c* of the rectangular base **120**.

The bottom portion **141** of the inverted U-shaped forward section **118** includes a downwardly extending projection **142** (FIG. **47**). The downwardly extending projection **142** includes a cylindrical stem portion **143** and defines a threaded opening **140** extending through the projection **142**. A central axis through the threaded opening **140** defines and is coincident with the axis of rotation DGR of the drive gear **650**. The upper and lower arcuate recesses **120***e*, **120***f* are centered about the drive gear axis of rotation DGR and the central axis of the threaded opening **140**.

The throughbore **115** of the gearbox housing **113** provides a receptacle for the pinion gear **610** and its associated bearing support assembly **630** while the upper and lower arcuate recesses **120***e*, **120***f* provide clearance for the drive gear **650** and its associate bearing support assembly **660**. Specifically, with regard to the bearing support assembly **630**, the cylindrical body **637** of the larger sleeve bushing **632** fits within the cylindrical cavity **129** of the inverted U-shaped forward section **118**. The enlarged forward head **636** of the sleeve bushing **632** fits within the forward cavity **126** of the forward section **118**. The cylindrical cavity **129** and the forward cavity **126** of the inverted U-shaped forward section **118** are both part of the throughbore **115**.

With regard to the upper and lower arcuate recesses **120***e*, **120***f*, the upper recess **120***e* provides clearance for the first bevel gear **652** of the drive gear **650** as the drive gear **650** rotates about its axis of rotation DGR upon the first bevel gear **652** being driven by the pinion gear **610**. The wider lower recess **120***f* provides clearance for the second spur gear **654** of the drive gear **650** as the spur gear **654** enacts with the driven gear **328** to rotate the rotary knife blade **300** about its axis of rotation R. As can best be seen in FIGS. **39** and **40**, the downwardly extending projection **142** and stem **143** provide seating surfaces for the ball bearing assembly **662**, which supports the drive gear **650** for rotation within the rectangular base **120** of the gearbox housing **113**. A cleaning port **136** (FIGS. **47** and **48**) extends through the bottom portion **141** of inverted U-shaped forward section **118** and a portion of the base **120** of the gearbox housing **113** to allow cleaning fluid flow injected into the throughbore **115** of the gearbox housing **113** from the proximal end **122** of the gearbox housing **113** to flow into the upper and lower arcuate recesses **120***e*, **120***f* for purpose of cleaning the drive gear **650**.

As can be seen in FIGS. **39** and **40**, an inner surface **145** of the cylindrical rearward section **116** of the gearbox housing **113** defines a threaded region **149**, adjacent the proximal end **122** of the gearbox housing **113**. The threaded region **149** of the gearbox housing **113** receives a mating threaded portion **262** (FIG. **2**B) of the elongated central core **252** of the hand piece retaining assembly **250** to secure the hand piece **200** to the gearbox housing **113**. As seen in FIGS. **38-44**, an outer surface **146** of the cylindrical rearward section **116** of the gearbox housing **113** defines a first portion **148** adjacent the proximal end **122** and a second larger diameter portion **147** disposed forward or in a forward direction FW of the first portion **148**. The first portion **148** of the outer surface **146** of the cylindrical rearward portion **116** of the gearbox housing **113** includes a plurality of axially extending splines **148***a*. The plurality of splines **148***a* accept and interfit with four ribs **216** (FIG. 2B) formed on an inner surface **201** of a distal end portion **210** of the hand piece **200**. The coacting plurality of splines **148***a* of the gearbox housing **113** and the four ribs **216** of the hand piece **200** allow the hand piece **200** to be oriented at any desired rotational position with respect to the gearbox housing **113**.

The second larger diameter portion **147** of the outer surface **146** of the cylindrical rearward section **116** of the gearbox housing **113** is configured to receive a spacer ring **290** (FIG. 2B) of the hand piece retaining assembly **250**. As can be seen in FIG. 8A, the spacer ring **290** abuts and bears against a stepped shoulder **147***a* defined between the cylindrical rearward section **116** and the inverted U-shaped forward section **118** of the gearbox housing **113**. That is, an upper portion **134** of the inverted U-shaped forward section **118** is slightly radially above a corresponding upper portion **132** of the cylindrical rearward section **116** of the gearbox housing **113**. A rear or proximal surface **292** (FIG. 2B) of the spacer ring **290** acts as a stop for an axially stepped collar **214** of the distal end portion **210** of the hand piece **200** when the hand piece **200** is secured to the gearbox housing **113** by the elongated central core **252** of the hand piece retaining assembly **250**.

The second larger diameter portion **147** of the outer surface **146** also includes a plurality of splines (seen in FIGS. **41** and **46**). The plurality of splines of the second portion **147** are used in connection with an optional thumb support (not shown) that may be used in place of the spacer ring **290**. The thumb support provides an angled, outwardly extending support surface for the operator's thumb. The plurality of splines of the second portion **149** are utilized in connection with the optional thumb support to allow the operator to select a desired rotational orientation of the thumb support with respect to the gearbox housing **113** just as the plurality of splines **148***a* of the first portion **148** allow the operator to select a desired rotational orientation of the hand piece **200** with respect to the gearbox housing **113**.

Frame Body **150**

Also part of the head assembly **111** is the frame or frame body **150**, best seen in FIGS. **45** and **49-52**. The frame body **150** receives and removably supports both the gearbox assembly **112** and the blade-blade housing combination **550**. In this way, the frame body **150** releasably and operatively couples the gearbox assembly **112** to the blade-blade housing combination **550** such that the gear train **604** of the gearbox assembly **112** operatively engages the driven gear **328** of the rotary knife blade **300** to rotate the knife blade **300** with respect to the blade housing **400** about the axis of rotation R.

The frame body **150** includes the arcuate mounting pedestal **152** disposed at a forward portion **151** (FIG. 2C) of the frame **150**, the central cylindrical region **154**, and a rectangular base **180** (FIG. **48**) disposed below the central cylindrical region **154**. The arcuate mounting pedestal **152** of the frame body defines the seating region **152***a* (FIGS. 22C and **51**) to receive the mounting section **402** of the blade housing **400** and secure the blade-blade housing combination **550** to the frame body **150**. The central cylindrical region **154** and the rectangular base **180** of the frame body **150** define a cavity **155** (FIGS. **45** and **49**) which slidably receives the gearbox housing **113**. The frame body cavity **155** is comprised of an upper socket **156** defined by the central cylindrical region **154** and a lower horizontally extending opening **190** defined by and extending through the central rectangular base **180**.

The central rectangular base **180** of the frame body **150** includes a bottom wall **182** and a pair of side walls **184** that extend upwardly from the bottom wall **182**. As is best seen in FIGS. **49** and **50**, a pair of bosses **186** extend inwardly from the pair of side walls **184**. Rearward facing surfaces **187** of the pair of bosses **186** each include a threaded opening **188**. The lower horizontally extending opening **190** defined by the rectangular base **180** includes two parts: a generally rectangular portion **190***a* extending rearwardly from the pair of boss surfaces **187**; and a forward portion **190***b* that extends through the rectangular base **180** to the seating region **152***a* of the frame body **150**.

To secure the gearbox assembly **112** to the frame body **150**, the gearbox assembly **112** is aligned with and moved toward a proximal end **157** of the frame body **150**. As can best be seen in FIG. **45**, the socket **156** defined by the central cylindrical region **154** of the frame body **150** is configured to slidably receive the inverted U-shaped forward section of the gearbox housing **113** and the rectangular portion **190***a* of the horizontally extending opening **190** of the rectangular base **180** is configured to slidably receive the rectangular base **120** of the gearbox housing **113**. The upper surface **130** of the gearbox housing **113** is slidably received within the inner surface **158** of the central cylindrical region **154** of the frame body **150**.

When the gearbox assembly **112** is fully inserted into the frame body **150**, the front wall **120***a* of the base **120** of the gearbox housing **113** abuts the rearward facing surfaces **187** of the pair of bosses **186** of the rectangular base **180** of the frame body **150**. Further, the horizontally extending openings **121** of the gearbox housing base **120** are aligned with the horizontally extending threaded openings **188** of the pair of bosses **186** of the frame body rectangular base **180**. A pair of threaded fasteners **192** (FIG. **45**) pass through the openings **121** of the gearbox housing base **120** and thread into the threaded openings **188** of the pair of bosses **186** of the frame body rectangular base **180** to releasably secure the gearbox assembly **112** to the frame body **150**. The openings **121** of the gearbox housing base **180** are partially threaded to prevent the fasteners **192** from fall out of the openings **121** when the gearbox housing **113** is not coupled to the frame body **150**.

The openings **121** of the gearbox housing base **120** include countersunk end portions **121***a* (FIG. **45**) to receive the enlarged heads of the pair of threaded fasteners **192** such that the enlarged heads of the fasteners **192**, when tightened into the frame body **150**, are flush with the rear wall **120***b* of the base **120**. The threaded fasteners **192** include narrow body portions relative to the enlarged heads and larger diameter threaded portions such that the fasteners **192** remain captured within their respective gearbox housing openings **121** when the gearbox housing **113** is not coupled to the frame body **150**. Relative movement between the gearbox assembly **112** and the frame body **150** is constrained by the threaded interconnection of the gearbox housing **113** to the frame body **150** via the threaded fasteners **192** and the abutting surfaces of the rectangular base **120** of the gearbox housing **113** and the rectangular base **180** of the frame body **150**.

Additionally, the frame body **150** releasably receives the blade-blade housing combination **550** and thereby operatively couples the blade-blade housing combination **550** to the gearbox assembly **112**. As can best be seen in FIGS. **51** and **52**, the pair of arcuate arms **160**, **162** of the frame body **150** define the arcuate mounting pedestal **152**. The mounting pedestal **152**, in turn, defines the seating region **152***a* that releasably receives the mounting section **402** of the blade housing **400**. Specifically, the arcuate mounting pedestal **152** includes an inner wall **174**, an upper wall **176** extending radially in the forward direction FW from an upper end of the inner wall **174**, and a lower wall or ledge **178** extending radially in a forward direction FW from a lower end of the inner wall **174**.

When the blade housing mounting section **402** is properly aligned and moved into engagement with the frame body arcuate mounting pedestal **152**: 1) the outer wall **406** of the blade housing mounting section **402** bears against the mounting pedestal inner wall **174** of the frame body **150**; 2) the first upper end **408** of the blade housing mounting section **402** bears against the mounting pedestal upper wall **176** of the frame body **150**; and 3) a radially inwardly stepped portion **406***a* of the outer wall **406** of the blade housing mounting section **402** bears against an upper face and a forward face of the radially outwardly projecting mounting pedestal lower wall or ledge **178** of the frame body **150**.

The respective threaded fasteners **170**, **172** of the frame body **150** are threaded into the threaded openings **420***a*, **422***a* of the mounting inserts **420**, **422** of the blade housing mounting section **402** to secure the combination blade-blade housing **550** to the frame body **150**. Assuming that the gearbox assembly **112** is coupled to the frame body **150**, when the blade-blade housing combination **550** is secured to the frame body **150**, the second spur gear **654** of the drive gear **650** of the gearbox assembly **112** engages and meshes with the driven gear **328** of the rotary knife blade **300** of the blade-blade housing combination **550**. Thus, when the gearbox assembly **112** and the blade-blade housing combination **550** are secured to the frame body **150**, the gear train **604** of the gearbox assembly **112** is operatively engaged with the driven gear **328** of the rotary knife blade **300** to rotatably drive the blade **300** within the blade housing **400** about the blade axis of rotation R. Like the threaded fasteners **192** of the gearbox housing **113** that secure the gearbox housing **113** to the frame body **150**, the threaded fasteners **170**, **172** of the frame body **150** include narrow bodies and larger diameter threaded portions such that the fasteners remain captured in the partially threaded openings **160***a*, **162***a* of the arcuate arms **160**, **162**.

To remove the combination blade-blade housing **550** from the frame body **150**, the pair of threaded fasteners **170**, **172** of the frame body **150** are unthreaded from the threaded openings **420***a*, **420***b* of the blade housing mounting inserts **420**, **422**. Then, the blade-blade housing combination **550** is moved is the forward direction FW with respect to the frame body **150** to disengage the blade-blade housing combination **550** from the head assembly **111**.

A forward wall **154***a* of the central cylindrical region **154** of the frame body **150** includes a projection **198** that supports a steeling assembly **199** (FIG. **2**C). The steeling assembly **199** includes a support body **199***a*, spring biased actuator **199***b*, and a push rod **199***c* with a steeling member **199***d* affixed to a bottom of the push rod **199***c*. The steeling assembly support body **199***a* is affixed to the projection **198**. When the actuator **199***b* is depressed by the operator, the push rod **199***c* moves downwardly and the steeling member **199***d* engages the blade edge **350** of the knife blade **300** to straighten the blade edge **350**.

Hand Piece **200** and Hand Piece Retaining Assembly **250**

The handle assembly **110** includes the hand piece **200** and the hand piece retaining assembly **250**. As can be seen in FIG. **2**B, the hand piece **200** includes the inner surface **201** and the outer gripping surface **204**. The inner surface **201** of the hand piece **200** defines the axially extending central opening or throughbore **202**. The outer gripping surface **204** of the hand piece **200** extends between an enlarged proximal end portion **206** and the distal end portion **210**. A front face or wall **212** of the hand piece **200** includes an axially stepped collar **214** that is spaced rearwardly and serves an abutment surface for a spacer ring **290** of the hand piece retaining assembly **250**. The inner surface **201** of the hand piece **200** defines the four ribs **216**, as previously described, which permit the hand piece **200** to be oriented in any desired rotational position with respect to the gearbox housing **113**. A slotted radial opening **220** in the front face **212** of the hand piece **200** receives an optional actuation lever (not shown). The optional actuation lever, if used, allows the operator to actuate the power operated rotary knife **100** by pivoting the lever toward the gripping surface **204** thereby engaging the drive mechanism **600** to rotatably drive the rotary knife blade **300**.

The hand piece retaining assembly **250**, best seen in FIGS. **2** and **2**B, releasably secures the hand piece **200** to the gearbox housing **113**. The hand piece retaining assembly **250** includes the elongated central core **252** which extends through the central opening **202** of the hand piece **200**. The elongated core **252** threads into the threaded opening **149** (FIG. **48**) at the proximal or rearward end **122** of the gearbox housing **113** to secure the hand piece **200** to the gearbox housing **113**.

The hand piece retaining assembly **250** also includes the spacer ring **290** (FIG. **2**B). When the hand piece **200** is being secured to the gearbox housing **113**, the spacer ring **290** is positioned on the second cylindrical portion **147** (FIG. **48**) of the outer surface **146** of the cylindrical rearward section **116** of the gearbox housing **113**. The spacer ring **290** is positioned to abut the stepped shoulder **147***a* defined between the larger second portion **147** of the outer surface **146** of the cylindrical rearward portion **116** and the inverted U-shaped forward section **118** of the gearbox housing **113**. When the hand piece **200** is secured to the gearbox housing **113** by the elongated central core **252**, the spacer ring **290** is sandwiched between the hand piece **200** and the stepped shoulder **147***a* of the gearbox housing **113**.

As can best be seen in FIGS. **2**B and **8**, the elongated central core **252** of the hand piece retaining assembly **250** includes an inner surface **254** and an outer surface **256** extending between a distal or forward reduced diameter end portion **264** and the enlarged proximal or rearward end portion **260**. The inner surface **254** of the elongated central core **252** defines a throughbore **258** extending along the longitudinal axis LA of the handle assembly **110**. The elongated central core **252** also includes a threaded portion **262** on the outer surface **256** at the forward reduced diameter end portion **264**. The outer surface **256** of the elongated core **252** includes a radially outwardly stepped shoulder **265**.

When the elongated central core **252** is inserted through the central throughbore **202** and the threaded portion **262** of the core **252** is threaded into the threaded opening **149** of the gearbox housing **113**, the hand piece **200** is secured to the gearbox housing **113**. Specifically, the hand piece **200** is prevented from moving in the forward axial direction FW along the handle assembly longitudinal axis LA by the spacer ring **290**. The rear surface **292** of the spacer ring **290** acts as a stop for the axially stepped collar **214** of the distal end portion **210** of the hand piece **200** to prevent movement of the hand piece **200** in the forward direction FW. The hand piece **200** is prevented by moving in the rearward axial direction RW along the handle assembly longitudinal axis LA by the radially outwardly stepped shoulder **265** of the elongated central core **252**.

As can be seen in FIG. **8**, the stepped shoulder **265** of the elongated central core **252** bears against a corresponding inwardly stepped shoulder **218** of the hand piece **200** to prevent movement of the hand piece **200** in the rearward direction RW. As mentioned previously, the spacer ring **290** may be replaced by an optional operator thumb support. Additionally, a strap attachment bracket (not shown) may be disposed between the spacer ring **290** and the gearbox housing **113**. The strap attachment bracket, if used, provides an attachment point for an optional operator wrist strap (not shown).

Drive Shaft Latching Assembly **275**

The elongated central core **252** of the hand piece retaining assembly **250** includes the enlarged rearward or proximal end portion **260**. The enlarged end portion **260** supports a drive shaft latching assembly **275** which engages a first coupling **710** (FIGS. **1** and **53**) of an outer sheath **704** of the shaft drive assembly **700** to secure the outer sheath **704** of the shaft drive assembly **700** to the handle assembly **110** and thereby ensures operative engagement of a first male fitting **714** of the inner drive shaft **702** within the female socket **622** of the pinion gear input shaft **612**. The inner surface **254** of the elongated central core **252** also includes an inwardly stepped shoulder **266** (FIG. **8**) that provides a stop for a distal portion **711** of the first coupling **710** of the shaft drive assembly **700**.

As is best seen in FIG. **2**B, the enlarged rearward end portion **260** of the elongated central core **252** of the hand piece retaining assembly **250** defines a generally U-shaped slot **268** that extends partially through the end portion **260** in a direction orthogonal to the longitudinal axis LA of the handle assembly **110**. The rearward end portion **260** also defines a central opening **270** (FIG. **8**) that is aligned with and part of the throughbore **258** of the elongated central core **252**. The central opening **270** ends at the inwardly stepped shoulder **266**. An end wall **272** of the rearward end portion **260** of the elongated central core **252** includes a peripheral cut-out **274**. The peripheral cut-out **274** is best seen in FIGS. **2**, **2**B and **6**.

Disposed in the U-shaped slot **268** of the elongated central core **252** is the drive shaft latching assembly **275** (best seen in schematic exploded view in FIG. **2**B) that releasably latches or couples the shaft drive assembly **700** to the handle assembly **110**. The drive shaft latching assembly **275** includes a flat latch **276** and a pair of biasing springs **278** inserted in the slot **268**. The flat latch **276** of the drive shaft latching assembly **275** includes a central opening **280** that is substantially equal to the size of the opening **270** of the enlarged end portion **260** of the elongated central core **252**.

The latch **276** is movable between two positions in a direction orthogonal to the longitudinal axis LA of the handle assembly **110**: 1) a first, locking position wherein the opening **280** of the latch **276** is offset from the opening **270** defined by the enlarged end portion **260** of the elongated central core **252**; and 2) a second release position wherein the opening **280** of the latch **276** is aligned with the opening **270** defined by the enlarged end portion **260** of the elongated central core **252**. The biasing springs **278**, which are trapped between peripheral recesses **281** in a bottom portion **282** of the latch **276** and the enlarged end portion **260** of the elongated central core **252**, bias the latch **276** to the first, locking position.

When the latch **276** is in the first, locking position a lower portion **286** of the latch **276** adjacent the latch opening **280** extends into the opening **270** of the enlarged end portion **260** of the core **252**. This can be seen schematically, for example in FIG. **6**. Movement of the latch **276** with respect to the enlarged end portion **260** is limited by the engagement of a holding pin **284** extending through a radially extending channel **283** formed in the latch **276**. The holding pin **284** bridges the U-shaped slot **268** of the enlarged end portion **260** and extends through the channel **283**. The channel **283** constrains and limits an extent of the radial movement of the latch **276** with respect to the enlarged end portion **260** of the elongated central core **252**.

Drive Mechanism **600**

As can best be seen in the schematic depiction of FIG. **53**, the knife blade **300** is rotatably driven in the blade housing **400** by the drive mechanism **600**. Within the power operated rotary knife **100**, the drive mechanism **600** includes the gearbox **602** supported by the gearbox housing **113**. The gearbox **602**, in turn, is driven by the flexible shaft drive assembly **700** and the drive motor **800** that are operatively coupled to the gearbox **602**. The flexible shaft drive assembly **700** is coupled to the handle assembly **110** by the drive shaft latching assembly **275**. A portion of the flexible shaft drive assembly **700** extends through the elongated central core **252** of the hand piece retaining assembly **250** and engages the pinion gear **610** to rotate the pinion gear about its axis of rotation PGR and thereby rotate the rotary knife blade **300** about its axis of rotation R.

As can best be seen in FIGS. **1** and **53**, the drive mechanism **600** includes the flexible shaft drive assembly **700** and the drive motor **800**. The shaft drive assembly **700** includes an inner drive shaft **702** and an outer sheath **704**, the inner drive shaft **702** being rotatable with respect to the outer sheath **704**. Affixed to one end **706** of the outer sheath **704** is the first coupling **710** that is adapted to be releasably secured to the enlarged rearward end portion **260** of the elongated central core **252** of the hand piece retaining assembly **250**. Affixed to an opposite end **708** of the outer sheath **704** is a second coupling **712** that is adapted to be releasably secured to a mating coupling **802** of the drive motor **800**.

When the first coupling **710** of the shaft drive assembly **700** is affixed to the hand piece **200**, the first male drive fitting **714** disposed at one end **716** of the inner drive shaft **702** engages the female socket or fitting **622** of the pinion gear input shaft **612** to rotate the pinion gear **610** about the pinion gear axis of rotation PGR. The rotation of the pinion gear **610** rotates the drive gear **650** which, in turn, rotates the rotary knife blade **300** about it axis of rotation R. When the second coupling **712** of the shaft drive assembly **700** is received by and affixed to the drive motor coupling **802**, a second drive fitting **718** disposed at an opposite end **720** of the inner drive shaft **702** engages a mating socket or fitting **804** (shown in dashed line in FIG. **53**) of the drive motor **800**. Engagement of the second drive fitting **718** of the inner drive shaft **702** and the drive motor fitting **804** provides for rotation of the inner drive shaft **702** by the drive motor **800**.

In the first, locking position of the latch **276** of the drive shaft latching assembly **275**, the lower portion **286** of the latch **276** extending into the opening **270** of the enlarged end portion **260** of the elongated central core **252** engages the first coupling **710** of the shaft drive assembly **700** to secure the shaft drive assembly **700** to the handle assembly **110** and insure the mating engagement of the first male drive coupling **714** of the drive shaft **702** to the female socket or fitting **622** of the pinion gear input shaft **612**. In the second, release position, the latch **276** is moved radially such that the opening **280** of the latch **276** is aligned with and coextensive with the opening **270** of the enlarged end portion **260** of the elongated central core **252** thus allowing for removal of the first coupling **710** of the shaft drive assembly **700** from the hand piece **200**.

The drive motor **800** provides the motive power for rotating the knife blade **300** with respect the blade housing **400** about the axis of rotation R via a drive transmission that includes the inner drive shaft **702** of the drive shaft assembly **700** and the gear train **604** of the gear box **602**. The drive motor **800** may be an electric motor or a pneumatic motor.

Alternately, the shaft drive assembly **700** may be eliminated and the gear train **604** of the gearbox **602** may be directly driven by an air/pneumatic motor or an electric motor disposed in the throughbore **258** of the elongated central core **252** of the hand piece retaining assembly **250** or in the throughbore **202** of the hand piece **200**, if a different hand piece retaining structure is used. A suitable air/pneumatic motor sized to fit within a hand piece of a power operated rotary knife is disclosed in U.S. non-provisional patent application Ser. No. 13/073,207, filed Mar. 28, 2011, entitled "Power Operated Rotary Knife With Disposable Blade Support Assembly", inventors Jeffrey Alan Whited, David Curtis Ross, Dennis R. Seguin, Jr., and Geoffrey D. Rapp (attorney docket BET-019432 US PRI). Non-provisional patent application Ser. No. 13/073,207 is incorporated herein in its entirety by reference.

Securing Shaft Drive Assembly **700** to Handle Assembly **110**

To secure the shaft drive assembly **700** to the hand piece **200**, the operator axially aligns the first coupling **710** of the drive shaft assembly **700** along the longitudinal axis LA of the handle assembly **110** adjacent the opening **270** defined by the enlarged end portion **260** of the elongated central core **252** of the hand piece retaining assembly **250**. The operator positions his or her thumb on the portion **288** of the latch **276** accessible through the peripheral cut-out **274** of the enlarged end portion **260** and slides the latch **276** radially inwardly to the second, release position, When the latch **276** is in the release position, the operator moves a forward portion **711** (FIG. **53**) of the first coupling **710** into the throughbore **258** of the elongated central core **252**.

After the forward portion **711** of the first coupling **710** is a received in the elongated central core **252** of the hand piece retaining assembly **250**, the operator then releases the latch **276** and continues to move the first coupling **710** further into the throughbore **258** of the central core **252** until the latch **276** (which is biased radially outwardly by the biasing springs **278**) snap fits into a radial securement groove **722** formed in an outer surface of the first coupling **710** of the shaft drive assembly **700**. When the latch **276** extends into the securement groove **722** of the first coupling **710**, the first coupling **710** is secured to the handle assembly elongated central core **252** and the first male drive fitting **714** of the inner drive shaft **702** is in operative engagement with the female socket or fitting **622** of the pinion gear input shaft **612**.

To release the shaft drive assembly **700** from the handle assembly elongated central core **252**, the operator positions his or her thumb on the portion **288** of the latch **276** accessible through the peripheral cut-out **274** of the enlarged end portion **260** of the elongated central core **252** and slides the latch **276** radially inwardly to the second, release position. This action disengages the latch **276** from the securement groove **722** of the first coupling **710** of the drive shaft assembly **700**. At the same time, the operator moves the first coupling **710** in the axial rearward direction RW out of the throughbore **258** of the elongated central core **252** and away from the handle assembly **110**. This will result in the first male drive fitting **714** of the drive shaft **702** being disengaged from the female fitting **622** of the pinion gear input shaft **612**.

Rotary Knife Blade Styles

As previously mentioned, depending on the cutting or trimming task to be performed, different sizes and styles of rotary knife blades may be utilized in the power operated rotary knife **100** of the present disclosure. Also, as previously mentioned, rotary knife blades in various diameters are typically offered ranging in size from around 1.2 inches in diameter to over 7 inches in diameter. Selection of a blade diameter will depend on the task or tasks being performed. Additionally, different styles or configurations of rotary knife blades are also offered. For example, the style of the rotary knife blade **300** schematically depicted in FIGS. **1-53** and discussed above is sometimes referred to as a "flat blade" style rotary knife blade. The term "flat" refers to the profile of the blade section **304** and, in particular, to a cutting angle CA (FIG. **24**) of the blade section **304** with respect to a plane CEP that is congruent with a cutting edge **350** of the blade **300**. The angle CA of the blade section **304** with respect to the cutting edge plane CEP is relatively large. As can be seen in FIG. **24**, the cutting angle CA, that is, the angle between the blade section **304** and the plane CEP, as measured with respect to the blade section inner wall **354** is an obtuse angle, greater than 90°. This large, obtuse cutting angle CA is referred to as a "shallow" blade cutting profile. As can be seen in FIG. **55**, the inner wall **360** is generally smooth, frustoconical shape. As the product P is being trimmed or cut by the flat blade **300**, the cut material layer CL**1** moves easily along the inner wall **360** the flat blade **300**. The flat blade **300** is particularly useful for trimming thicker layers of material from a product, e.g., trimming a thicker layer of fat or meat tissue from a piece of meat, as the power operated rotary knife **100** is moved over the product in a sweeping motion. This is true because even thicker layers of cut or trimmed material will flow with minimal drag or friction over the inner wall **360** of the flat blade **300**.

Another blade profile is shown in the "hook blade" style rotary knife blade which is schematically depicted at **1000** in FIG. **56**. Here the cutting angle CA with respect to the plane CEP defined by the cutting edge **1050**, may be about the same or slightly larger or smaller than the cutting angle CA of the rotary knife blade **300** (see FIG. **24**). However, the inner profile of the hook blade **1000** is less planar and more V-shaped that the inner profile of the flat blade **300**. That is, as the inner surface of the blade curves radially inwardly as one moves from the blade section **1004** to the body section **1002**. This inward curvature of the inner surface of the hook blade **1000** results in a less smooth and more curved path of travel for cut or trimmed material, as compared with the flat blade **300**. Thus, the hook blade **1000** is particularly useful for trimming relatively thin layers of material from a product, for example, trimming a thin layer of fat or meat tissue from a relatively planar, large piece of meat, as the power operated rotary knife **100** is moved over the product in a sweeping motion. For trimming thicker layers of material from a product, the hook blade **1000** would not be as efficient because the curved path of travel of the cut or trimmed material layer would result in the power operated rotary knife **100** experiencing more drag and resistance during cutting or trimming. Thus, more effort would be required by the operator to move and manipulate the power operated rotary knife **100** to make the desired cuts or trims.

As can also be seen, the shape of the rotary knife blade body **1002** is also different than the body **302** of the flat rotary knife blade **300**. Accordingly, the shape of a blade support section **1450** of a blade housing **1400** is also modified accordingly from the shape of the blade support section **450** of the blade housing **400** when used in the power operated rotary knife **100**. That is, the shape of a particular rotary knife blade selected to be used in the power operated rotary knife **100** will sometimes require modification of the associated blade housing for the power operated rotary knife **100**. However, the blade-blade housing bearing structure **500** and gear train **604**, as discussed above, are utilized to support and drive the blade **1000**. Additionally, as discussed above, the driven gear **1030** of the knife blade **1000** is spaced axially below the bearing race **1020**.

A more aggressive blade profile is shown in the "straight blade" style rotary knife blade which is schematically depicted at **1500** in FIG. **57**. The cutting angle CA is smaller than the cutting angles of the rotary knife blades **300** and **1000**. Indeed, the cutting angle CA of the knife blade **1500** is an acute angle of less than 90° with respect to the plane CEP defined by the cutting edge **1550**. The cutting angle CA of the straight blade **1500** is very "steep" and more aggressive than the flat blade **300** or the hook blade **1000**. A straight blade is particularly useful when make deep or plunge cuts into a product, i.e., making a deep cut into a meat product for the purpose of removing connective tissue/gristle adjacent a bone.

As can also be seen, the shape of the knife blade body **1502** is also different than the body **302** of the flat rotary knife blade **300**. Accordingly, the shape of a blade support section **1950** of a blade housing **1900** is also modified accordingly from the shape of the blade support section **450** of the blade housing **400** when used in the power operated rotary knife **100**. However, the blade-blade housing bearing structure **500** and gear train **604**, as discussed above, are utilized to support and drive the blade **1000**. Additionally, as discussed above, the driven gear **1530** of the knife blade **1500** is spaced axially below the bearing race **1520**.

Other rotary knife blades styles, configurations, and sizes exist and may also be used with the power operated rotary knife **100**. The blade-blade housing structure **500** of the present disclosure and the other features, characteristics and attributes, as described above, of the power operated rotary knife **100** may be used with a variety of rotary knife blades styles, configurations, and sizes and corresponding blade housings. The examples recited above are typical blade styles (flat, hook, and straight), but numerous other blade styles and combination of blade styles may be utilized, with an appropriate blade housing, in the power operated rotary knife **100** of the present disclosure, as would be understood by one of skill in the art. It is the intent of the present application to cover all such rotary knife blade styles and sizes, together with the corresponding blade housings, that may be used in the power operated rotary knife **100**.

Second Exemplary Embodiment—Power Operated Rotary Knife **2100**

Overview

A second exemplary embodiment of a power operated rotary knife of the present disclosure is shown generally at **2100** in FIGS. **59** and **60**. The power operated rotary knife **2100** includes a handle assembly **2110**, a detachable head assembly **2111**, and a drive mechanism **2600**. The head assembly **2111**, best seen in FIGS. **60-68**, of the power operated rotary knife **2100** includes a gearbox assembly **2112**, a rotary knife blade **2300**, a blade housing **2400**, and a blade-blade housing support or bearing structure **2500**.

The rotary knife blade **2300** is supported for rotation with respect to the blade housing **2400** by the blade-blade housing bearing structure **2500**, which includes, in one exemplary embodiment, an elongated rolling bearing strip **2502** (FIGS. **70** and **71**) disposed in an annular passageway **2504** (FIG. **71**) formed between opposing bearing surfaces **2319**, **2459** of the rotary knife blade **2300** and the blade housing **2400**, respectfully. An assembled combination of the rotary knife blade **2300**, the blade housing **2400**, and the blade-blade housing bearing structure **2500** will be referred to as the blade-blade housing combination **2550** (FIG. **67**). The blade-blade housing bearing structure **2500** is similar to the blade-blade housing bearing structure **500** of the power operated rotary knife **100**, that is, the blade-blade housing bearing structure **2500** both releasably secures the rotary knife blade **2300** to the blade housing **2400** and provides a bearing structure to support the rotary knife blade **2300** for rotation about an axis of rotation R' (FIGS. **59** and **67**).

The gearbox assembly **2112** includes a gearbox housing **2113** and a gearbox **2602** defining a gear train **2604**. Similar to the gear train **604** of the power operated rotary knife **100**, the gear train **2604** of the power operated rotary knife **2100** includes a pinion gear **2610** and a drive gear **2650**. The pinion gear **2610** is rotatably driven about a pinion gear axis of rotation PGR' (FIG. **67**) by a flexible shaft drive assembly (not shown). The flexible shaft drive assembly (not shown) is similar to the flexible shaft drive assembly **700** of the power operated rotary knife **100**.

The pinion gear **2610**, in turn, rotatably drives a drive gear **2650** about a drive gear axis of rotation DGR' (FIG. **67**). As was the case with the gear train **604** of the power operated rotary knife **100** of the first embodiment, the drive gear **2650** is a double gear that includes a first upper bevel gear **2652** which meshes with a set of bevel gear teeth **2616** of a gear head **2614** of the pinion gear **2610** to rotate the drive gear **2650**, while a second lower spur gear **2654** of the drive gear **2650** engages a drive gear **2328** of the rotary knife blade **2300** forming an involute gear drive **2658** (FIG. **67**) to rotate the knife blade **2300** about its axis of rotation R'.

Other components of the drive mechanism **2600** of the power operated rotary knife **2100** include components external to the head and handle assemblies **2111**, **2110** of the power operated rotary knife **2100**. These external components include a drive motor (not shown) and the flexible shaft drive assembly (not shown) which rotates the pinion gear **2610**. Such components of the power operated rotary knife **2100** are similar to the corresponding components discussed with respect to the power operated rotary knife **100**, e.g., the flexible shaft drive **700** and drive motor **800**.

As is best seen in FIG. **60**, the handle assembly **2110** includes a hand piece **2200** and a hand piece retaining assembly **2250**. The handle assembly **2110** extends along a longitudinal axis LA' (FIGS. **59** and **67**), which is substantially orthogonal to and intersects the rotary knife blade axis of rotation R'. The hand piece retaining assembly **2250** includes an elongated central core **2252** and a handle spacer ring **2290**. The elongated central core **2252** includes an outer surface **2256** that includes a threaded portion **2262** at a distal end **2264** of the core **2252**. The threaded portion **2262** of the elongated core **2252** threads into threads **2149** (FIG. **89**) formed on an inner surface **2145** of a cylindrical rearward section **2116** of the gearbox housing **2113** to secure the hand piece **2200** to the gearbox housing **2113**.

The power operated rotary knife **2100** is especially suited to be used with annular rotary knife blades having a smaller blade outer diameter, for example, a blade outer diameter on the order of three and half (3½) inches or less. When using a small diameter rotary knife blade, there is a desire to reduce the physical size or "footprint" of the head assembly and, particularly, the size of the frame body so that the rotary knife blade, the blade housing and the head assembly are all proportionately smaller in size compared to power operated rotary knife used in conjunction with a larger diameter annular rotary knife blades. For example, with a smaller diameter rotary knife blade, the cutting opening of the rotary knife blade is smaller and the cutting or trimming to be done with the power operated rotary knife tends to be smaller in size and more precise. While the size of the blade housing is typically proportional in size to the size of the rotary knife blade, a large head assembly and, specifically, a large frame body may tend to obscure the operator's view of the cutting region and the cutting or trimming operation being performed.

The size and shape of a handle or hand piece of the handle assembly is generally determined by ergonomic considerations, e.g., the size of an average operator's hand, gripping comfort, etc. Thus, the size of the hand piece is typically the same for both large and small blade diameter power operated rotary knives.

In the power operated rotary knife **2100**, the size of the head assembly **2111** is effectively reduced by certain features that distinguish it from the head assembly **111** of the power operated rotary knife **100**, described above. Specifically, the frame body **2150** of the power operated rotary knife **2100** is reduced in size compared to the frame body **150** of the power operated rotary knife **100**. Recall that in the power operated rotary knife **100**, the blade-blade housing combination **550** was secured to an arcuate mounting pedestal **152** at a front portion **151** of the frame body **150**.

In the power operated rotary knife **2100**, the frame body **2150** does not include an arcuate mounting pedestal at a front portion of the frame body. Instead, the blade-blade housing combination **2550** of the power operated rotary knife **2100** is mounted directly to the gearbox housing **2113**, specifically, to an L-shaped mounting pedestal **2132** (FIG. **62**) defined by a pair of bosses **2131** of a forward mounting section **2120** of the gearbox housing **2113**. In addition to the forward mounting section **2120** at a distal end **2124** of the gearbox housing **2113**, the gearbox housing **2113** includes an inverted U-shaped central section **2118** and a cylindrical rearward section **2116** at a proximal end **2122** of the housing **2113**.

In the power operated rotary knife **100**, the gearbox assembly **112** including the gearbox housing **113** was slidably received within in the cavity **155** defined by the frame body **150**, somewhat akin to a dresser drawer being slid into a dresser. The gearbox housing **113** was moved in the forward direction FW along the handle assembly longitudinal axis LA relative to the frame body **150** to be slidably received within the frame body cavity **155**. The frame body **150** surrounded both the top and the bottom of the gearbox housing **113**. In the power operated rotary knife **2100**, the frame body **2150** is smaller and less bulky. The frame body **2150** and a thin frame body bottom cover **2190** are secured together to cover, protect, and support the gearbox housing **2113**. The frame body **2150** defines a cavity **2174** (FIG. **90**) and has an open bottom wall **2160**. This configuration allows the frame body **2150** to be moved in a downward direction DW' (FIG. **68**) orthogonal to the handle assembly longitudinal axis LA' to slide over the forward mounting section **2120** and the inverted U-shaped central section **2118** of the gearbox housing **2113**. When assembled, a bottom wall **2160** of the frame body **2150** is flush with corresponding bottom surfaces of the forward mounting section **2120** and the inverted U-shaped central section **2118** of the gearbox housing **2113**. The frame body bottom cover **2190** is then secured to the bottom wall **2160** of the frame body **2150**. Attachment of the frame body bottom cover **2190** to the frame body **2150** therefore effectively seals the gearbox housing **2113**.

As noted above, the hand piece **200** of the power operated rotary knife **100** and the hand piece **2200** of the power operated rotary knife **2100** are approximately the same size. As can be seen in FIGS. **60**, **97** and **98**, the handle spacer ring **2290** of the handle assembly **2110** includes a body portion **2294** that tapers radially inwardly from the hand piece **2200** to the frame body **2150**. In the power operated rotary knife **100**, the handle spacer ring **290** (FIG. **2**) was cylindrical and not tapered. This is another indication that the frame body **2150** of the power operated rotary knife **2100** is smaller in size than the corresponding frame body **150** of the power operated rotary knife **100**.

As discussed, the head assembly **2111** of the power operated rotary knife **2100** includes structural differences compared to the head assembly **111** of the power operated rotary knife **100** that result in a smaller physical "footprint" of the head assembly **2111** of the power operated rotary knife **2100**. However, it should be recognized that, if desired, the power operated rotary knife **2100** may effectively be used with large diameter rotary knife blades just as the power operated rotary knife **100** could, if desired, be effectively used with small diameter rotary knife blades.

For brevity, components and assemblies of the power operated rotary knife **2100** that are substantially similar to corresponding components and assemblies of the power operated rotary knife **100**, such as the handle assembly **2110**, the blade-blade housing structure **2500**, the drive mechanism **2600**, the gearbox **2602**, the gear train **2604**, the flexible shaft drive assembly, and the drive motor, among others, will not be described in detail below. It being understood by one of ordinary skill in the art that the discussion of the structure and function of the components and assemblies of the power operated rotary knife **100**, set forth above, is applicable to and is incorporated into the discussion of the power operated rotary knife **2100**, set forth below.

Rotary Knife Blade **2300**

In one exemplary embodiment and as best seen in FIGS. **71-74**, the rotary knife blade **2300** of the power operated rotary knife **2100** is a one-piece, continuous annular structure that is supported for rotation about the axis of rotation R'. The rotary knife blade **2300** includes a body section **2302** and a blade section **2304** extending axially from the body **2302**. The body **2302** of the rotary knife blade **2300** includes an upper end **2306** and a lower end **2308** spaced axially apart from the upper end **2306**. The knife blade body **2302** further includes an inner wall **2310** and an outer wall **2312** spaced radially apart from the inner wall **2310**. The blade section **2304** of the rotary knife blade **2300** includes a blade edge **2350** defined at a distal end portion **2352** of the blade section **2304**. The blade section **2304** further includes an inner wall **2354** and an axially spaced apart outer wall **2356**. A short angled portion **2358** bridges the inner and outer walls **2354**, **2356**. As can best be seen in FIG. **74**, the blade edge **2350** is formed at the intersection of the short angled portion **2358** and the blade section inner wall **2354**. The rotary knife blade **2300** defines an inner wall **2360** which is formed by the inner wall **2310** of the body **2302** and the inner wall **2354** of the blade section **2304**. In one exemplary embodiment, the rotary knife blade **2300** includes a knee or discontinuity **2360*a*** in the body region of the inner wall **2360**, although it should be appreciated that, depending on the specific configuration of the rotary knife blade **2300**, the blade may be formed such that there is no discontinuity in the inner wall **2360**.

The rotary knife blade **2300** is different in configuration than the rotary knife blades **300**, discussed previously. As explained previously, the rotary knife blade **300** is typically referred to as a "flat blade" style rotary knife blade, while the rotary knife blade **2300** is typically referred to as a "hook blade" style rotary knife blade (FIG. **56**). As was the case with the power operated rotary knife **100**, the power operated rotary knife **2100** may be used with a variety of rotary knife blade styles and sizes, provided that an appropriately configured mating blade housing is provided. As can best be seen in FIG. **74**, in a hooked style blade, both the inner and outer walls **2354**, **2356** the blade section **2304** extends generally downwardly and radially inwardly with respect to the axis of rotation R'.

Each time the rotary knife blade **2300** is sharpened, material will be removed from the distal end portion **2352** and the cutting edge **2350** will move along the blade section **2304** generally in an upward direction UP' (FIG. **74**). Stated another way, the axial extent of both the inner and outer walls **2354**, **2356** of the blade section **2304** will decrease with repeated sharpening of the blade **2300**. When repeated sharpening of the rotary knife blade **2300** causes the distal end portion **2352** to impinge on a knee **2308***a* of the blade body **2312** defining the lower end **2308** of the body **2302**, the rotary knife blade **2300** would be at or near the end of its useful life.

A radially inwardly step **2314** (FIG. **74**) of the body outer wall **2312** defines a line of demarcation between a radially narrower, upper gear and bearing region **2316** of the blade body **2302** and a radially wider, lower support region **2318** of the body **2302**. As can be seen in FIG. **74**, the upper gear and bearing region **2316** is narrow in cross section being recessed inwardly from an outermost radial extent **2318***a* of the lower support region **2318** defined by the blade body outer wall **2312**. The upper gear and bearing region **2316**, in one exemplary embodiment, is generally rectangular in cross section and includes an upper section **2316***a*, a generally vertical or axially extending middle section **2316***b*, and a generally vertically extending lower section **2316***c*. As can be seen, the lower section **2316***c* of the upper gear and bearing region **2316** is radially recessed with respect to the outermost radial extent **2318***a* of the outer wall **2312**. The middle section **2316***b* of the upper gear and bearing region **2316** is radially recessed with respect to the lower section **2316***c*. And, the upper section **2316***a* of the upper gear and bearing region **2316** is radially recessed with respect to the middle section **2316***b*.

The rotary knife blade **2300** includes the bearing surface **2319**. In one exemplary embodiment of the power operated rotary knife **2100** and as best seen in FIGS. **71** and **74**, the rotary knife blade bearing surface **2319** comprises a bearing race **2320**, which is defined by and extends radially inwardly into the outer wall **2312** in the middle section **2316***b* of the upper gear and bearing region **2316**. In one exemplary embodiment, the knife bearing race **2320** defines a generally arcuate bearing face **2322** in a central portion **2324** of the bearing race **2320**. As can be seen the middle section **2316***b* of the upper gear and bearing region **2316** includes vertical portions **2326***a*, **2326***b* respectively extending axially above and below the bearing race **2320**.

The body outer wall **2312** in the lower section **2316***c* of the upper gear and bearing region **2316** of rotary blade body **2302** defines a driven gear **2328** comprising a set of gear teeth **2330** formed so as to extend radially outwardly in a stepped portion **2331** of the outer wall. The driven gear **2328** is axially below the bearing race **2320**, that is, closer to the second lower end **2308** of the blade body **2302**. The driven gear **2328**, in one exemplary embodiment, defines a plurality of vertically or axially oriented spur gear teeth **2332**.

Advantageously, as can be seen in FIG. **74**, the set of gear teeth **2330** of the rotary knife blade driven gear **2328** are axially spaced from the upper end **2306** of the rotary knife blade body **2302** by the recessed upper section **2316***a* of the upper gear and bearing region **2316** and are also axially spaced from arcuate bearing race **2320** of the body **2302** by the lower vertical portion **2326***b* of the middle section **2316***b* of the upper gear and bearing region **2316** below the bearing race **2320**. The set of gear teeth **2330** of the rotary knife blade drive gear **2328** are also advantageously axially spaced from the lower end **2308** of the blade body **2302** by the lower support portion **2318** of the knife blade body **2302**. Advantageously, the bearing race **2320** of the rotary knife blade **2300** is also axially spaced from the upper and lower ends **2306**, **2308** of the blade body **2302**.

The set of gear teeth **2330** of the driven gear **2328** of the rotary knife blade **2300** is axially spaced from the upper end **2306** of the knife blade body **2302**. This advantageously protects the set of gear teeth **2330** from damage that they would otherwise be exposed to if, as is the case with conventional rotary knife blades, the set of gear teeth **2330** were positioned at the upper end **2306** of the blade body **2302** of the rotary knife blade **2300**. Additionally, debris are generated by the power operated rotary knife **2100** during the cutting/trimming operations. Generated debris include pieces or fragments of bone, gristle, meat and/or fat that are dislodged or broken off from the product being cut or trimmed by the power operated rotary knife **2100**. Debris may also include foreign material, such as dirt, dust and the like, on or near a cutting region of the product being cut or trimmed. Advantageously, spacing the set of gear teeth **2330** from both axial ends **2306**, **2308** of the knife blade body **2302**, impedes or mitigates the migration of such debris into the region of the knife blade driven gear **2328**. Debris in the region of knife blade driven gear **2328** may cause or contribute to a number of problems including blade vibration, premature wear of the driven gear **2328** or the mating drive gear **2650** of the gear train **2604**, and "cooking" of the debris.

Similar advantages exist with respect to axially spacing the blade bearing race **2320** from the upper and lower ends **2306**, **2308** of the blade body **2302**. As will be explained below, the rotary knife blade body **2302** and the blade housing **2400** are configured to provide radially extending projections or caps which provide a type of labyrinth seal to impede ingress of debris into the regions of the knife blade driven gear **2328** and the blade-blade housing bearing structure **2500**. These labyrinth seal structures are facilitated by the axial spacing of the knife blade drive gear **2328** and the blade bearing race **2320** from the upper and lower ends **2306**, **2308** of the blade body **2302** of the rotary knife blade **2300**.

As can best be seen in FIGS. **60** and **67**, a lower spur gear **2654** of the drive gear **2650** of the gear train **2604** meshes with the spur gear teeth **2332** of the knife blade driven gear **2328** to rotate the rotary knife blade **2300** with respect to the blade axis of rotation R'. This gearing combination defines an involute spur gear drive, as was previously described with respect to the gear train **604** of the drive mechanism **600** of the power operated rotary knife **100**, between the gearbox **2602** and the knife blade **2300** to rotate the knife blade **2300** with respect to the blade housing **2400**.

As can be best seen in FIG. **71**, in order to impede ingress of fragments or pieces of meat, bone, and/or gristle generated during cutting/trimming operations, and/or other debris into the driven gear **2328** of the rotary knife blade **2300**, the outer wall **2312** in the lower support portion of blade body **2318** includes a radially outwardly extending projection or cap **2318***b*. The outwardly extending cap **2318***b* includes the outermost radial extent **2818***a* of the lower support portion **2318** of the rotary knife blade body **2302**. As can best be seen in FIG. **74**, the cap **2318***b* is axially aligned with and, when viewed in an upward direction UP' from the lower end **2308** of the knife blade body **2302**, overlies at least a portion of the set of gear teeth **2330**.

A radial outer surface **2330***a* of the set of gear teeth **2330**, when viewed in three dimensions, defines a first imaginary cylinder **2346** (shown schematically in dashed line in FIG. **74**). That is, the first imaginary cylinder **2346** is defined by the gear tips **2330***a* of each of the gear teeth of the set of gear teeth **2330**. A radial inner surface **2330***b* of the set of gear teeth **2330**, when viewed in three dimensions, defines a second, smaller diameter imaginary cylinder **2347** (also shown schematically in dashed line in FIG. **74**). That is, the second imaginary cylinder **2347** is defined by the gear root **2330***b* of each of the gear teeth of the set of gear teeth **2330**. Viewed in an upward direction UP' from a lower end **2308** of the knife blade body **2302**, the cap **2318***b* is aligned with and overlies at least a portion of an annulus **2349** defined between the first imaginary cylinder **2346** and the second, smaller diameter cylinder **2347**. As the annulus **2349** is coincident with a volume occupied by the set of gear teeth **2330**, the cap **2318***b* is aligned with and overlies at least a portion of the set of gear teeth **2330**. Further, the cap **2318***b* extends radially outwardly beyond the imaginary cylinder **2346** defined by the radial outer surface **2330***a* of the set of gear teeth **2330**.

As can best be seen schematically in FIG. **71**, the outwardly extending cap **2318***b* is axially aligned with and overlies at least a portion of a bottom wall or end **2458** of a blade support section **2450** of the blade housing **2400** to form a type of labyrinth seal and minimize ingress of debris into the driven gear **2328**. The overlapping cap **2318***a* of the rotary knife blade body **2302** and the bottom wall **2458** of the blade support section **2450** of the blade housing **2400** inhibit ingress of debris from entering between the outer wall **2312** of the blade body **2302** of the rotary knife blade **2300** and the blade housing **2400** and working into the region of the knife blade driven gear **2328**. As best seen schematically in FIG. **71**, for clearance purposes, there is a small axial gap between an upper surface **2318***c* of the cap **2318***b* and the bottom wall **2458** of the blade housing blade support section **2450**. The upper surface **2318***c* of the cap **2318***c* is a portion of the radially inward step **2314** defining the line of demarcation between upper gear and bearing portion **2316** of the blade body **2302** and the lower support portion **2318** of the blade body **2302**.

An upper portion of the knife blade inner wall **2360** defines a cutting opening CO' (FIGS. **61**, **63** and **69**) of the power operated rotary knife **2100**. That is, a layer of material is cut or trimmed from a product being processed, such as a layer of meat or fat being trimmed from an animal carcass, by moving power operated rotary knife **2100** such that the rotary knife blade **2300** and blade housing **2400** move through the carcass. As the rotary knife blade **2300** and blade housing **2400** move through the carcass, the cut or trimmed layer of material moves with respect to the power operated rotary knife **2100** through the cutting opening CO' defined by the rotary knife blade **2300**.

Blade Housing **2400**

In one exemplary embodiment and as best seen in FIGS. **70** and **75-79**, the blade housing **2400** of the power operated rotary knife **2100** comprises one-piece, continuous annular structure that includes the mounting section **2402** and the blade support section **2450**. The blade housing is continuous about its perimeter, that is, unlike prior split-ring annular blade housings, the blade housing **2400** of the present disclosure has no split along a diameter of the housing to allow for expansion of the blade housing diameter. The blade-blade housing bearing structure **2500** secures the rotary knife blade **2300** to the blade housing **2400**. Accordingly, removal of the knife blade **2300** from the blade housing **2400** is accomplished by removing the elongated rolling bearing strip **2502** of the blade-blade housing bearing structure **2500** from the power operated rotary knife **2100**. The blade-blade housing bearing structure **2500** permits use of the continuous blade housing **2400** because there is no need to expand the blade housing diameter to remove the knife blade **2300** from the blade housing **2400**.

The multiple advantages of a continuous annular blade housing of the present disclosure, including the exemplary blade housings **400** and **2400**, have been discussed above with respect to the blade housing **400** and will not be repeated here. With respect to the blade housing **2400**, the mounting section **2402** extends radially outwardly from the blade support section **2450** and subtends an angle of approximately 120° or, stated another way, extends approximately ⅓ of the way around the circumference of the blade housing **2400**. The mounting section **2402** is both axially thicker and radially wider than the blade support section **2450**.

The mounting section **2402** includes an inner wall **2404** and a radially spaced apart outer wall **2406** and a first upper end **2408** and an axially spaced apart second lower end **2410**. At forward ends **2412**, **2414** of the mounting section **2402**, there are tapered regions **2416**, **2418** (FIG. **75**) that transition between the upper end **2408**, lower end **2410** and outer wall **2406** of the mounting section **2402** and the corresponding upper end **2456**, lower end **2458** and outer wall **2454** of the blade support section **2450**. The mounting section **2402** defines an opening **2420** (FIGS. **70** and **75**) that extends radially between the inner and outer walls **2404**, **2406**. The radially extending opening **2420** is bounded by and extends between upright supports or pedestals **2422** and an upper surface **2428***a* of a base **2428** that bridges the pedestals **2422**. The pedestals **2422** extend axially upwardly from an upper surface **2428***a* of the base **2428**.

As can best be seen in FIGS. **82-84**, the base **2428** and the pedestals **2422** above the base **2428** together define two axially extending apertures **2430** between the upper and lower ends **2408**, **2410** of the mounting section **2402**. The base apertures **2430** receive a pair of threaded fasteners or screws **2434**. The threaded fasteners **2434** pass through the base apertures **2430** and thread into respective threaded openings **2130** of a horizontal planar seating surface **2133** of the L-shaped mounting pedestal **2132** (FIG. **88**) defined by the forward mounting portion **2120** of the gearbox housing **2113** to releasably secure the blade-blade housing combination **2550** to the gearbox housing **2113** of the head assembly **2111**. When blade-blade housing combination **2550** is secured to the gearbox housing **2113** using the threaded fasteners, the upper end **2408** of the mounting section **2402** of the blade housing **2400** is seated on the horizontal planar seating surface **2133** of the L-shaped mounting pedestal **2132** of the forward mounting portion **2120** of the gearbox housing **2113**. The outer wall **2406** of the mounting section **2402** of the blade housing **2400** is seated on a vertical planar seating surface **2134** of the L-shaped mounting pedestal **2132** of the forward mounting portion **2120** of the gearbox housing **2113**.

The radially extending opening **2420** of the blade housing mounting section **2402** includes a narrower upper portion **2420***a* and a wider lower portion **2420***b*. A relative width of the opening **2420** is defined by rearward facing surfaces **2438** of the pedestals **2422** that comprise a portion of the outer wall **2406** of the blade housing mounting portion **2402**. The opening **2420** is sized to receive a removable blade housing plug **2440** (FIGS. **80-82**). The blade housing plug **2440** is removably received in the mounting section opening **2420**. When the blade housing plug **2440** is removed from the opening **2420**, access is provided to the elongated rolling bearing strip **2502** of the blade-blade housing bearing structure **2500**. The elongated rolling bearing strip **2502** must be inserted to secure the rotary knife blade **2300** to the blade housing **2500** and must be removed to permit the rotary knife blade **2300** to be removed from the blade housing **2400**.

The blade housing plug **2440** is positioned in the opening **2420** and releasably attached to the blade housing **2400** via a pair of set screws **2446** (FIG. **70**) that, when tightened bear against the upper surface **2428***a* of the mounting section base **2428**. Stepped shoulders **2441** formed in opposite sides

2440*e*, **2440***f* of blade housing plug **2440** bear against mating stepped shoulders **2424** of the pair of pedestals **2422** to secure the blade housing plug **2440** with respect to the blade housing mounting section opening **2420**. When installed in the blade housing mounting section opening **2420**, the blade housing plug **2440** inhibits debris generated during cutting/trimming operations (e.g., pieces or fragments of fat, gristle, bone, etc.) and other foreign materials from migrating to and accumulating on or adjacent the elongated rolling bearing strip **2502** of the blade-blade housing bearing structure **2500** or the driven gear **2328** of the rotary knife blade **2300**.

As can best be seen in FIGS. **71** and **79**, the blade support section **2450** includes an inner wall **2452** and radially spaced apart outer wall **2454** and a first upper end **2456** and an axially spaced second lower end **2458**. The blade support section **2450** extends about the entire 360° circumference of the blade housing **2400**. The blade support section **2450** in a region of the mounting section **2402** is continuous with and forms a portion of the inner wall **2404** of the mounting section **2402**. The blade support section inner wall **2452** defines the bearing surface **2459**. In one exemplary embodiment of the power operated rotary knife **2100** and as best seen in FIGS. **71** and **79**, the bearing surface **2459** of the blade housing **2400** comprises a bearing race **2460** that extends radially inwardly into the inner wall **2452**. In one exemplary embodiment, a central portion **2462** of the blade housing bearing race **2460** defines a generally arcuate bearing face **2464**.

As can best be seen in FIG. **71**, the blade support section upper end **2456** defines a radially inwardly extending projection or cap **2456***a* that overlies a part of a radially inwardly stepped portion **2348** of the outer wall **2312** of the rotary knife blade body **2302** between the recessed upper section **2316***a* of the gear and bearing portion **2316** and the upper vertical portion **2326***a* of the middle section **2316***b* of the gear and bearing portion **2316** above bearing race **2320**. The overlap of the projection or cap **2456***a* of the blade housing **2400** and the inwardly stepped portion **2348** of the rotary knife blade body **2402** protects the blade-blade housing bearing structure **2550**. In the assembled blade-blade housing combination **2550**, the cap **2456***a* is axially aligned with and overlies at least a portion of the rotary knife blade bearing structure **2320** and the set of gear teeth **2330** of the knife blade driven gear **2328**.

Specifically, the overlap of the cap **2456***a* of the blade housing **2400** and the inwardly stepped portion **2348** of the rotary knife blade body **2402** forms a type of labyrinth seal. The labyrinth seal inhibits the entry of debris resulting from cutting and trimming operations and other foreign materials into the annular passageway **2504** between facing bearing surfaces **2319**, **2459** of rotary knife blade **2300** and the blade housing **2400** and through which the rolling bearing strip **2502** of the blade-blade housing bearing structure **2500** traverses. As best seen schematically in FIG. **71**, for clearance purposes, there is a small radial gap between a terminal end **2456***b* of the bearing region cap **2456***a* of the blade housing **2400** and the recessed upper section **2316***a* of the gear and bearing portion **2316** the rotary knife blade body **2402**.

As can best be seen in FIG. **79**, advantageously the blade housing bearing race **2460** is axially spaced from both the upper and lower ends **2456**, **2458** of the blade support section **2450**. Specifically, there is a portion **2466** of the inner wall **2452** of the blade support section **2450** extending axially between the blade housing bearing race **2460** and the cap **2456***a* and there are two axially extending portion **2468**, **2470** of the inner wall **2452** extending axially between the bearing race **2460** and the blade support section lower end **2458**. The first portion **2468** of the inner wall **2452** is directly below the bearing race **2460**. The second portion **2470** of the inner wall **2452** is radially offset outwardly from the first portion **2468** and is adjacent the lower end **2458** of the blade housing **2400**. As can be seen in FIG. **71**, the second portion **2470** provides clearance for the driven gear **2328** of the rotary knife blade **2300**.

The blade support section **2450** is configured to be relatively thin in radial cross section such that the combination of the knife blade **2300** and blade housing **2400** define a small cross sectional area. Minimizing drag of the combination of the blade **2300** and blade housing **2400** during cutting and trimming operations reduces operator effort required to move and manipulate the power operated rotary knife **2100** as the rotary knife blade **2300** and blade housing **2400** move through a product being cut or trimmed.

As is best seen in FIG. **77**, the right tapered region **2416** (as viewed from a front of the power operated rotary knife **2100**) of the blade housing mounting section **2402** includes a cleaning port **2480** for injecting cleaning fluid for cleaning the blade housing **2400** and the knife blade **2300** during a cleaning process. The cleaning port **2480** includes an entry opening **2481** in the outer wall **2406** of the mounting section **2402** and extends through to exit opening **2482** in the inner wall **2404** of the mounting section **2402**. A portion of the exit opening **2482** in the mounting section inner wall is congruent with and opens into a region of the bearing race **2460** of the blade housing **2400**. The cleaning port **2480** provides for injection of cleaning fluid into bearing race regions **2320**, **2460** of the knife blade **2300** and blade housing **2400**, respectively, and the driven gear **2328** of the knife blade **2300**.

Blade Housing Plug **2440**

As can be seen in FIGS. **70** and **80**-**82**, the blade housing plug **2440** includes an upper end **2440***a*, an axially spaced apart a lower end **2440***b*, an inner wall **2440***c* and a radially spaced apart outer wall **2440***d*. The blade housing plug **2440** also includes the pair of stepped shoulders **2441** formed in opposite sides **2440***e* of the blade housing plug **2440**. The inner wall **2440***c* defines an arcuate bearing race **2442** (FIGS. **80**-**82**) that continues the bearing race **2460** of the blade housing blade section inner wall **2452**. When the blade housing plug **2440** is installed in the blade housing plug opening **2420** of the blade housing mounting section **2402**, the radially inner wall **2440***c* of the blade housing plug **2440** defines a portion of the blade housing bearing race **2460** such that the blade housing bearing race **2460** is continuous about substantially the entire 360° circumference of the blade support section **2450**.

As can best be seen in FIG. **81**, the blade housing plug **2440** includes an generally rectangular opening **2445** that extends through the blade housing plug **2440** from outer wall **2440***d* to the inner wall **2440***c*. The upper end **2440***a* of the blade housing plug **2440** also defines a first axially extending arcuate recess **2443** (FIG. **80**). When the blade housing plug **2440** is installed in the blade housing plug opening **2420**, the opening **2445** of the blade housing plug **2440** receives the lower spur gear **2654** of the drive gear **2650** of the drive train **2604** such that the spur gear **2654** meshes with and rotatably drives the driven gear **2328** of the rotary knife blade **2300** and the arcuate recess **2443** of the blade housing plug **2440** provides clearance for the upper bevel gear **2652** of the drive gear **2650**.

A portion of the upper end **2440***a* of the blade housing plug **2440** includes a radially inwardly extending bearing region cap **2444** (FIG. **82**) that continues the radially inwardly extending bearing region cap **2456***a* of the blade support section **2450** of the blade housing **2400**. The upper end **2440***a* of the blade housing plug **2440**, when installed in the blade housing opening **2420**, is flush with and functions as portion of the upper end **2408** of the mounting section **2402** of the blade housing **2400** for purposes of mounting the blade housing **2400** to the horizontal planar seating surface **2133** of the L-shaped mounting pedestal **2132** of the forward mounting portion **2120** of the gearbox housing **2113**. Similarly, the outer wall **2440***d* of the blade housing plug **2440**, when installed in the blade housing opening **2420**, is flush with and functions as a portion of the outer wall **2406** of the mounting section **2402** of the blade housing **2400** for purposes of mounting the blade housing **2400** to the vertical planar seating surface **2134** of the L-shaped mounting pedestal **2132** of the forward mounting portion **2120** of the gearbox housing **2113**.

The blade housing plug **2440** is removably secured to the blade housing **2400** by the two set screws **2446** (FIG. **70**). The set screws **2446** pass through a pair of threaded openings **2447** that extend through the blade housing plug **2440**, from the upper end **2440***a* though the lower end **2440***b* of the plug. When the blade housing plug **2440** is installed in the blade housing opening **2420** and the set screws **2446** are tightened, the lower ends of the set screws **2446***a* bear against upper surface **2428***a* of base **2428** of the blade housing mounting section **2402** to secure the blade housing plug **2440** to the blade housing mounting section **2402**.

Blade-Blade Housing Bearing Structure **2500**

The power operated rotary knife **2100** includes the blade-blade housing bearing structure **2500** (best seen in FIGS. **60**, **67** and **66-71**) that: a) secures the knife blade **2300** to the blade housing **2400**; b) supports the knife blade **2300** for rotation with respect to the blade housing **2400** about the rotational axis R'; and c) defines the rotational plane RP' (FIG. **67**) of the knife blade **2300**. The blade-blade housing bearing structure **2500** is similar in structure and function to the blade-blade housing bearing structure **500** of the power operated rotary knife **100** and, accordingly, will be described briefly, with reference being made to the discussion above regarding the blade-blade housing structure **500**.

The blade-blade housing bearing structure **2500** comprises the elongated rolling bearing strip **2502** (FIGS. **60**, **70** and **71**) that is routed circumferentially about the axis of rotation R' of the knife blade **2300**. The blade-blade housing bearing structure **2500** further includes the blade housing bearing race **2460** and the knife blade bearing race **2320** and the annular passageway **2504** (FIG. **71**) defined therebetween.

The rolling bearing strip **2502** is routed between the knife blade **2300** and the blade housing **2400** through the passageway **2504** forming a circle or a portion of a circle about the knife blade axis of rotation R'. The elongated rolling bearing strip **2502**, in one exemplary embodiment, comprises a plurality of spaced apart rolling bearings, such as a plurality of ball bearings **2506** supported for rotation in a flexible separator cage **2508**. In one exemplary embodiment, the flexible separator cage **2508** comprises an elongated polymer strip, like the elongated polymer strip **520**, discussed previously. The plurality of ball bearings **2506** are held in spaced apart relationship in the flexible separator cage **2508**, as previously discussed with respect to the flexible separator cage **508**.

The plurality of ball bearings **2506** of the elongated rolling bearing strip **2502** are in rolling contact with and provide bearing support between the knife blade bearing race **2320** and the blade housing bearing race **2460**. At the same time, while supporting the knife blade **2300** for low friction rotation with respect to the blade housing **2400**, the elongated rolling bearing strip **2502** also functions to secure the knife blade **2300** with respect to the blade housing **2400**, that is, the bearing strip **2502** prevents the knife blade **2300** from falling out of the blade housing **2400** regardless of the orientation of the power operated rotary knife **2100**.

When the rolling bearing strip **2502** is inserted into the passageway **2504**, the plurality of ball bearings **2506** support the knife blade **2300** with respect to the blade housing **2400**. The plurality of ball bearings **2506** are sized that their radii are smaller than the respective radii of the arcuate bearing surfaces **2464**, **2322**. In one exemplary embodiment, the radius of each of the plurality of ball bearings **2506** is approximately 1 mm. or 0.039 inch. It should be appreciated however that the radius of the plurality of ball bearings **2506** may be somewhat larger or smaller than 1 mm. and may be smaller than or equal to the radii of the arcuate bearing surfaces **2464**, **2322**.

Gearbox **2603** and Gear Train **2604**

The drive mechanism **2600** (schematically shown in FIG. **60**) of the power operated rotary knife **2600** includes the gearbox **2602** for providing motive power for rotating the rotary knife blade **2300** about its axis of rotation R'. The gearbox **2602** includes the gear train **2604** and two bearing support assemblies, namely, a bearing support assembly **2630** that supports the pinion gear **2610** for rotation about the pinion gear rotational axis PGR', and a bearing support assembly **2660** that supports the drive gear **2650** for rotation about the drive gear rotational axis DGR'. The gear train **2604** of the power operated rotary knife **2100** includes the pinion gear **2610** and the drive gear **2650**. The drive gear **2650** includes the lower spur gear **2654** and an upper bevel gear **2652** which are axially spaced apart and aligned concentrically about the drive gear rotational axis DGR'. A gear head **2614** of the pinion gear **2610** meshes with the upper bevel gear **2652** of the drive gear **2650** to rotatably drive the drive gear **2650**. The pinion gear **2610**, in turn, is driven by the flexible shaft drive assembly (not shown) and rotates about the axis of rotation PGR' (FIG. **67**) of the pinion gear **2610**. The pinion gear **2610** includes an input shaft **2612** extending rearwardly of the gear head **2614**. The input shaft **2612** extends from a proximal end **2629** (FIG. **60**) to a distal end **2628** adjacent the gear head **2614**. The pinion gear input shaft **2612** includes a central opening **2618** (FIG. **66**). An interior surface **2620** of the input shaft **2612** defines a cross shaped female socket or fitting **2622** that receives a mating male drive fitting of the flexible shaft drive assembly (not shown) which provides for rotation of the pinion gear **2610**.

The pinion gear axis of rotation PGR' is substantially parallel to and coextensive or aligned with the handle assembly longitudinal axis LA'. At the same time, the drive gear **2650** rotates about the drive gear axis of rotation DOR' (FIG. **67**) which is substantially parallel to the rotary knife blade axis of rotation R' and is substantially orthogonal to and intersects the pinion gear axis or rotation PGR' and the handle assembly longitudinal axis LA'.

The pinion gear bearing support assembly **2630**, in one exemplary embodiment, includes a larger sleeve bushing **2632** and a smaller sleeve bushing **2640**. As can best be seen in FIG. **67**, the larger sleeve bushing **2632**, like the sleeve bushing **632** of the power operated rotary knife **100**, includes an annular forward head **2636** and a cylindrical body **2637**. The cylindrical body **2637** of the sleeve bushing **2632** defines a central opening **2634** that receives the input shaft **2612** of the pinion gear **2610** to rotatably support the pinion gear **2610** in the gearbox housing **2113**. The cylindrical body **2637** of the larger sleeve bushing **2632** is supported within a conforming cavity **2129** (FIGS. **67** and **89**) of the inverted U-shaped central section **2118** of the gearbox housing **2113**, while the enlarged forward head **2636** of the sleeve bushing **2632** fits within a conforming forward cavity **2126** of the U-shaped central section **2118** of the gearbox housing **2113**.

A flat **2638** (FIG. **60**) of the enlarged forward head **2636** of the larger sleeve bushing **2632** interfits with a flat **2128** (FIG. **87**) formed in the forward cavity **2126** of the inverted U-shaped central section **2118** of the gearbox housing **2113** to prevent rotation of the sleeve bushing **2632** within the gearbox housing **2113**. The cylindrical body **2639** of the larger sleeve bushing **2632** defining the central opening **2634** provides radial bearing support for the pinion gear **2610**. The enlarged head **2636** of the sleeve bushing **2632** also provides a thrust bearing surface for a rearward collar **2627** (FIG. **67**) of the gear head **2614** to prevent axial movement of the pinion gear **2610** in the rearward direction RW', that is, travel of the pinion gear **2610** along the pinion gear axis of rotation PGR', in the rearward direction RW'.

The bearing support assembly **2630** of the pinion gear **2610** also includes the smaller sleeve bushing **2640**. As can best be seen in FIG. **60**, with some slight differences, the smaller sleeve bushing **2640** is similar to the smaller sleeve bushing **640** of the power operated rotary knife **100**. As best seen in FIGS. **99** and **100**, the smaller sleeve bushing **2640** includes an annular forward head **2644** and a cylindrical rearward portion **2642**. A forward facing surface **2624** of the gear head **2614** of the pinion gear **2610** includes a central recess **2626** which is substantially circular in cross section and is centered about the pinion gear axis of rotation PGR'. The pinion gear central recess **2626** receives a cylindrical reward portion **2642** of the smaller sleeve bushing **2640**. The smaller sleeve bushing **2640** functions as a thrust bearing. The annular head **2644** of the smaller sleeve bushing **2640** provides a bearing surface for the gear head **2614** of the pinion gear **2610** and limits axial travel of the pinion gear **2610** in the forward direction FW', that is, travel of the pinion gear **2610** along the pinion gear axis of rotation PGR', in the forward direction FW'.

As can best be seen in FIGS. **62** and **99**, the annular head **2644** of the smaller sleeve bushing **2640** includes two parallel peripheral flats **2648** to prevent rotation of sleeve bushing **2640** with rotation of the pinion gear **2610**. The parallel flats **2648** of the sleeve bushing **2640** fit within and bear against two spaced-apart parallel shoulders **2179** (FIG. **93**) defined by a U-shaped recess **2178** of an inner surface **2176** of a forward wall **2156** of the frame body **2150**. The abutment of the parallel flats **2648** of the smaller sleeve bushing **2640** against the shoulders **2179** of the frame body **2150** prevents rotation of the sleeve bushing **2640** as the pinion gear **2610** rotates about its axis of rotation PGR'.

The drive gear bearing support assembly **2660**, in one exemplary embodiment, comprises a ball bearing assembly **2662** that supports the drive gear **2650** for rotation about the drive gear rotational axis DGR'. The drive gear bearing support assembly **2660** is secured to a downwardly extending projection **2142** (FIGS. **47** and **48**) of the inverted U-shaped central section **2118** of the gearbox housing **2113** by a fastener **2672**. The ball bearing assembly **2662** of the gearbox **2602** is similar to the drive gear ball bearing assembly **662** of the power operated rotary knife **100**.

Gearbox Housing **2113**

As can best be seen in FIGS. **68** and **83-89**, the gearbox housing **2113** is part of the gearbox assembly **2112** and defines a gearbox cavity or opening **2114** that supports the gear train **2604** of the gearbox **2602**. The gearbox housing **2113** includes the generally cylindrical rearward section **2116** (in the rearward direction RW' away from the blade housing **2400**), the inverted U-shaped central section **2118**, and the forward mounting section **2120**. The gearbox housing **2113** extends between the proximal end **2122** defined by the cylindrical rearward section **2116** and a distal end **2144** defined by the forward mounting section **2120**. The inverted U-shaped central section **2118** of the gearbox housing **2113** includes a rearward downwardly extending portion **2119** (FIG. **84**) and a forward portion **2125**.

The gearbox cavity or opening **2114** is defined in part by a throughbore **2115** which extends generally along the handle assembly longitudinal axis LA' through the gearbox housing **2113** from the proximal end **2122** to the forward portion **2125** of the inverted U-shaped central section **2118**. As can best be seen in FIG. **62**, the gearbox **2602** is supported in and extends from the gearbox cavity **2114**. Specifically, the gear head **2614** of the pinion gear **2610** extends in the forward direction beyond the forward portion **2125** of the gearbox housing **2113** and portions of the drive gear **2650** extend in the forward direction beyond the rearward downwardly extending portion **2119** of the U-shaped central section **2118** of the gearbox housing **2113**. The inverted U-shaped central section **2118** and the cylindrical rearward section **2116** combine to define an upper surface **2130** of the gearbox housing **2113**.

The forward mounting section **2120** of the gearbox housing **2113** includes the L-shaped blade housing mounting pedestal **2132** that functions as a seating region to releasably receive the blade-blade housing combination **2550**. The L-shaped blade housing mounting pedestal **2132** includes a pair of spaced apart bosses **2131** that extend downwardly and forwardly from the forward portion **2125** of the inverted U-shaped central section **2118**. As can best be seen in FIGS. **83-88**, the pair of bosses **2131** each include an upper horizontal portion **2131*a*** and a lower vertical portion **2131*b***. A downward facing surface of the upper horizontal portion **2131*a*** defines the first horizontal planar seating surface **2133** of the L-shaped blade housing mounting pedestal **2132**, while a forward facing surface of the lower vertical portion **2131*b*** defines the second vertical planar seating surface **2134** of the L-shaped blade housing mounting pedestal **2132**.

The vertical planar seating surface **2134** is substantially orthogonal to the first horizontal planar seating surface **2133** and parallel to the axis of rotation R' of the rotary knife blade **2300**. The horizontal planar seating surface **2133** is substantially parallel to the longitudinal axis LA' of the handle assembly **2110** and the rotational plane RP' of the rotary knife blade **2300**. The upper horizontal portion **2131*a*** of each of the bosses **2131** includes a threaded opening **2135** that receives a threaded fastener **2191**. Each of the threaded fasteners **2191** pass through a respective opening **2430** of the blade housing mounting section **2402** and thread into a respective threaded opening **2135** of the bosses **2131** to secure the blade-blade housing combination **2550** to the gearbox housing **2313**.

A bottom portion **2141** (FIGS. **62**, **83** and **84**) of the forward portion **2125** of the inverted U-shaped central section **2118** includes a downwardly extending projection **2142** (FIG. **83**). The downwardly extending projection **2142** includes a cylindrical stem portion **2143** and defines a threaded opening **2140** extending through the projection **2142**. A central axis through the threaded opening **2140** defines and is coincident with the axis of rotation DGR' of the drive gear **2650**. The rearward downwardly extending portion **2119** of the inverted U-shaped central section **2118** of the gearbox housing **2113** defines upper and lower arcuate recesses **2119*a***, **2119*b*** which provide for clearance of the bevel gear **2652** and the spur gear **2654** of the drive gear **2650**, respectively. The upper arcuate recess **2119*a*** and the wider lower arcuate recesses **2119*b*** are centered about the drive gear axis of rotation DGR' and the central axis of the threaded opening **2140**. The inner surfaces of the pair of bosses **2131** also include upper and lower recesses **2131*c***, **2131*d*** (best seen in FIG. **83**) that provide for clearance of the bevel gear **2652** and the spur gear **2654** of the drive gear **2650**, respectively.

The throughbore **2115** of the gearbox housing **2113** provides a receptacle for the pinion gear **2610** and its associated bearing support assembly **2630** while the upper and lower arcuate recesses **2119***a*, **2119***b* provide clearance for the drive gear **2650** and its associate bearing support assembly **2660**. Specifically, with regard to the pinion bearing support assembly **2630**, the cylindrical body **2637** of the larger sleeve bushing **2632** fits within the cylindrical cavity **2129** (FIG. **89**) of the inverted U-shaped central section **2118**. The enlarged forward head **2636** of the larger sleeve bushing **2632** fits within the forward cavity **2126** (FIGS. **83** and **89**) of the forward portion **2125**. The cylindrical cavity **2129** and the forward cavity **2126** of the inverted U-shaped central section **2118** are both part of the throughbore **2115**.

With regard to the upper and lower arcuate recesses **2119***a*, **2119***b*, the upper recess **2119***a* provides clearance for the first bevel gear **2652** of the drive gear **2650** as the drive gear **2650** rotates about its axis of rotation DGR' upon the first bevel gear **2652** being driven by the pinion gear **2610**. The wider lower recess **2119***b* provides clearance for the second spur gear **2654** of the drive gear **2650** as the spur gear **2654** coacts with the rotary knife blade driven gear **2328** to rotate the rotary knife blade **2300** about its axis of rotation R'. As can best be seen in FIGS. **67** and **83**, the downwardly extending projection **2142** and the stem **2143** provide seating surfaces for the ball bearing assembly **2662**, which supports the drive gear **2650** for rotation within the rearward downwardly extending portion **2119** of the inverted U-shaped central section **2118** of the gearbox housing **2113**.

A cleaning port **2136** (FIGS. **83** and **86**) extends through the bottom portion **2141** of the forward portion **2125** and through the rearward downwardly extending portion **2119** of the inverted U-shaped central section **2118** of the gearbox housing **2113**. The cleaning port **2136** allows cleaning fluid flow injected into the throughbore **2115** of the gearbox housing **2113** from the proximal end **2122** of the gearbox housing **2113** to flow into the upper and lower arcuate recesses **2119***a*, **2119***b* for purpose of cleaning the drive gear **2650**.

As can be seen in FIG. **89**, the inner surface **2145** of the cylindrical rearward section **2116** of the gearbox housing **2113** defines a threaded region **2149**, adjacent the proximal end **2122** of the gearbox housing **2113**. The threaded region **2149** of the gearbox housing **2113** receives the mating threaded portion **2262** (FIG. **60**) of the elongated central core **2252** of the hand piece retaining assembly **2250** to secure the hand piece **2200** to the gearbox housing **2113**. As seen in FIGS. **83**-**86** and **88**, an outer surface **2146** of the cylindrical rearward section **2116** of the gearbox housing **2113** defines a first portion **2148** adjacent the proximal end **2122** and a second larger diameter portion **2147** disposed forward or in a forward direction FW' of the first portion **2148**. The first portion **2148** of the outer surface **2146** of the cylindrical rearward portion **2116** of the gearbox housing **2113** includes a plurality of axially extending splines **2148***a*. As was the case with the gearbox housing **113** and the hand piece **200** of the power operated rotary knife **100**, the coacting plurality of splines **2148***a* of the gearbox housing **2113** and the ribs of the hand piece **2200** allow the hand piece **2200** to be oriented at any desired rotational position with respect to the gearbox housing **2113**.

The second larger diameter portion **2147** of the outer surface **2146** of the cylindrical rearward section **2116** of the gearbox housing **2113** is configured to receive a spacer ring **2290** (FIGS. **60** and **97**-**88**) of the hand piece retaining assembly **2250**. The spacer ring **2290** abuts and bears against a stepped shoulder **2147***a* defined between the cylindrical rearward section **2116** and the inverted U-shaped central section **2118** of the gearbox housing **2113**. A rear or proximal surface **2292** (FIGS. **97** and **98**) of the spacer ring **2290** acts as a stop for an axially stepped collar **2214** (FIG. **60**) of the distal end portion **2210** of the hand piece **2200** when the hand piece **2200** is secured to the gearbox housing **2113** by the elongated central core **2252** of the hand piece retaining assembly **2250**.

As can be seen in FIGS. **97** and **98**, a body portion **2294** of the handle spacer ring **2290** is tapered from a larger diameter proximal end **2296** to a smaller diameter distal end **2298**. The handle spacer ring body portion **2294** is tapered because, as can be seen in FIG. **60**, an outer diameter of the hand piece **2200** exceeds an outer diameter formed by the combination a proximal end **2158** of the frame body **2150** and the rearward downwardly extending portion **2119** of the inverted U-shaped central section **2118** of the gearbox housing **2113** adjacent the stepped shoulder **2147***a*. The outer diameter formed by the combination the frame body proximal end **2158** and the gearbox housing rearward downwardly extending portion **2119** adjacent the stepped shoulder **2147***a* is best seen in FIGS. **63** and **64**.

The second larger diameter portion **2147** of the outer surface **2146** of the cylindrical rearward section **2116** of the gearbox housing **2113** also includes a plurality of splines (seen in FIGS. **83**-**84** and **86**). The plurality of splines of the second larger diameter portion **2147** are used in connection with an optional thumb support (not shown) that may be used in place of the spacer ring **2290**, as previously described with respect to the power operated rotary knife **100**.

Frame Body **2150** and Frame Body Bottom Cover **2190**

As can best be seen in FIG. **62**, when the gearbox **2602** is supported within the gearbox housing **2113**, portions of the pinion gear **2610** and the drive gear **2650** are exposed, that is, extend outwardly from the gearbox housing **2113**. The frame body **2150** and frame bottom cover **2190**, when secured together form an enclosure around the gearbox housing **2113** that advantageously functions to impede entry of debris into the gearbox housing **2113**, the pinion gear **2610** and portions of the drive gear **2650**. Additionally, the frame body **2150** includes portions that are adjacent to and extend the first horizontal planar seating surface **2133** and the second vertical planar seating surface **2134** of the L-shaped blade housing mounting pedestal **2132** defined by the pair of bosses **2131** of the gearbox housing **2113**. This advantageously enlarges the effective seating region of the gearbox housing **2113** for a more secure attachment of the blade-blade housing combination **2550** to the gearbox housing **2113**.

As can best be seen in FIGS. **68** and **90**-**93**, the frame body **2150** includes a central cylindrical region **2154** and a pair of outwardly extending arms **2152** from the central cylindrical region **2154**. The frame body **2150** includes a forward wall **2156** at a proximal or forward end of the frame body **2150**. A central portion **2156***a* of the forward wall **2156** is defined by the central cylindrical region **2154**, while forwardly extending portions **2156***b* of the forward wall **2156** are defined by the outwardly extending arms **2152**. As is best seen in FIG. **91**, proceeding in a rearward direction RW' from the forward wall **2156** toward a proximal end **2158** of the frame body **2150**, there are two tapered regions **2159** where the outwardly extending arms **2152** curve inwardly and blend into the central cylindrical region **2154**.

The frame body **2150** includes an outer surface **2170** and an inner surface **2172**. The inner surface **2172** defines the cavity **2174** (FIG. **90**) that slidably receives portions of the gearbox housing **2113** including the forward mounting section **2120** and the inverted U-shaped central section **2118**. As can best be seen in FIG. **68**, the frame body **2150** includes a bottom wall **2160** that includes a first, lower planar bottom wall portion **2162** and a second, upper planar bottom wall portion **2164**. As can be seen, the upper planar bottom wall portion **2164** is offset in an upward direction UP' from the lower planar bottom wall portion **2162**. The bottom wall **2160** is open into the cavity **2174** which allows the frame body **2150** to be slid over the upper surface **2130** of the gearbox housing **2113** in a relative downward direction DW' with respect to the gearbox housing **2113**. Specifically, a central dome-shaped portion **2180** of the cavity **2174** is configured to slidably receive the inverted U-shaped central section **2118** of the gearbox housing **2113**, while a pair of square-shaped portions **2182** of the cavity **2174** (FIG. **92**) flanking the central dome-shaped portion **2180** are configured to slidably receive respective ones of the pair of bosses **2131** of the forward mounting section **2120** of the gearbox housing **2113**.

When the frame body **2150** is fully slid onto the gearbox housing **2113**, the lower planar portion **2162** of the bottom wall **2160** of the frame body **2150** is flush with a bottom surface **2137** (FIGS. **83**, **84** and **86**) of the rearward downwardly extending portion **2119** of the inverted U-shaped central section **2118** of the gearbox housing **2113** and with a bottom surface **2137** of the lower vertical portions **2131***b* of the pair of bosses **2131**. Additionally, the upper planar portion **2164** of the bottom wall **2160** is flush with the first horizontal seating surface **2133** of the L-shaped blade housing mounting pedestal **2132**.

The upper planar portion **2164** of the bottom wall **2160** of the frame body **2150** continues and extends the effective seating region of the first horizontal seating surface **2133** of the L-shaped blade housing mounting pedestal **2132** of the gearbox housing **2113** for a more secure attachment of the blade-blade housing combination **2550** to the gearbox housing **2113**. Similarly, as can best be seen in FIGS. **62**, **90** and **92**, a narrow vertical wall **2188** between the upper planar portion **2164** and the lower planar portion **2162** of the bottom wall **2160** of the frame body **2160** is flush with the second vertical seating surface **2134** of the L-shaped blade housing mounting pedestal **2132** of the gearbox housing **2113**. The narrow vertical wall **2188** continues and extends the effective seating region of the second vertical seating surface **2134** of the L-shaped blade housing mounting pedestal **2132** of the gearbox housing **2113** for a more secure attachment of the blade-blade housing combination **2550** to the gearbox housing **2113**.

As can best be seen in FIG. **92**, the lower planar portion **2162** of the bottom wall **2160** includes a pair of threaded openings **2166**. The threaded openings **2166** receive respective threaded fasteners **2192** to secure the frame body bottom cover **2190** to the frame body **2150**. The inner surface **2176** of the forward wall **2156** of the frame body **2150** includes the U-shaped recess **2178** which defines the pair of spaced apart shoulders **2179** (FIG. **93**). As previously explained with respect to the smaller sleeve bushing **2642** of the pinion gear bearing support assembly **2130**, the shoulders **2179** provide an abutment or bearing surface for the pair of flats **2648** of the smaller sleeve bushing **2642** to prevent rotation of the sleeve bushing **2642** with rotation of the pinion gear **2610**. As can best be seen in FIGS. **90** and **92**, the inner surface **2172** of the frame body **2150** includes a pair of arcuate recesses **2184** adjacent the lower portion **2162** of the bottom wall **2160**. The pair of arcuate recesses **2184** provide clearance for the spur gear **2154** of the drive gear **2650** and continue the clearance surface defined by the lower arcuate recess **2119***b* of the rearward downwardly extending portion **2119** of inverted U-shaped central section **2118** of the gearbox housing **2113**.

As can best be seen in FIGS. **90** and **94-96**, the frame body bottom cover **2190** is a thin planar piece that includes an upper surface **2191**, facing the gearbox housing **2113**, and a lower surface **2192**. The frame body cover **2190** includes a pair of openings **2194** extending between the upper and lower surfaces **2191**, **2192**. The frame body bottom cover **2190** is removably secured to the frame body **2150** by the pair of threaded fasteners **2199** that extend through respective ones of the pair of openings **2113** and thread into respective threaded openings **2166** in the lower planar portion **2162** of the bottom wall **2160** of the frame body **2150**. The pair of openings **2194** include countersunk head portions **2194***a* formed in the lower surface **2192** of the frame body bottom cover **2190** such that, when the frame body bottom cover **2190** is secured to the frame body **2150**, the enlarged heads of the threaded fasteners **2199** are flush with the lower surface **2192**.

The frame body bottom cover **2190** also includes a straight forward wall **2195** and a contoured rearward wall **2196**. When the frame body bottom cover **2190** is secured to the frame body **2150**, the forward wall **2195** is flush with, continues and extends the effective seating region of the second vertical seating surface **2134** of the L-shaped blade housing mounting pedestal **2132** of the gearbox housing **2113** for a more secure attachment of the blade-blade housing combination **2550** to the gearbox housing **2113**. The contour of the rearward wall **2196** of the frame body bottom cover **2190** is configured such that, when the frame body bottom cover **2190** is secured to the frame body **2150**, a peripheral portion of the lower surface **2192** adjacent the rearward wall **2196** engages and seats against the lower planar portion **2162** of the bottom wall **2160** of the frame body **2150** and the bottom surface **2137** of the rearward downwardly extending portion **2119** of the inverted U-shaped central section **2118** of the gearbox housing **2113**. Because of the contoured configuration of the rearward wall **2196**, the lower surface **2192** of the frame body bottom cover **2190** thereby seals against both the gearbox housing **2113** and the frame body **2150** to protect the gearbox **2602** and specifically the drive gear **2650** and the drive gear ball bearing assembly **2662** from ingress of debris into the drive gear region.

The upper surface **2191** of the frame body bottom cover **2190** includes a recess **2198** that provides for clearance of the head of the fastener **2672** that secures the drive gear ball bearing assembly **2662** to the stem **2143** of the gearbox housing **2113**.

Securing Blade-Blade Housing Combination to Head Assembly **2111**

To removably attach the blade-blade housing combination **2550** to the gearbox housing **2113**, the upper end **2408** of the mounting section **2402** of the blade housing **2400** is aligned adjacent the horizontal planar seating surface **2133** of the L-shaped blade housing mounting pedestal **2132** of the forward mounting section **2120** of the gearbox housing **2113** and the outer wall **2406** of the blade housing mounting section **2402** is aligned adjacent the vertical planar seating surface **2134** of the L-shaped blade housing mounting pedestal **2132**. Specifically, the mounting section **2402** of the blade housing **2400** is aligned with the forward mounting section **2120** of the gearbox housing **2113** such that the two vertical apertures **2430** extending through the mounting section base **2428** and the pair of upright pedestals **2422** of the mounting section base **2428** are aligned with the vertically extending threaded openings **2135** through the pair of bosses **2131** of the forward mounting section **2120** of the gearbox housing **2113**.

When the blade housing **2400** is properly aligned with the forward mounting section **2120** of the gearbox housing **2113**, the upper surface **2428***a* of the base **2428** of the blade housing mounting section **2402** and the upper end **2440***a* of the blade housing plug **2440** affixed to the blade housing **2400** are in contact with the horizontal planar seating surface **2133** of the L-shaped blade housing mounting pedestal **2132**. Additionally, the rearward surface **2428**c of the base **2428** of the blade housing mounting section **2402** and the outer wall **2440**d of the blade housing plug **2440** are in contact with the vertical planar seating surface **2134** of the L-shaped blade housing mounting pedestal **2132**.

To affix the assembled blade-blade housing combination **2550** to the gearbox housing **2113**, the fasteners **2434** are inserted into the two vertical apertures **2430** of the blade housing mounting section **2402** and threaded into respective ones of the vertically extending threaded openings **2135** through the upper horizontal portions **2131**a of the pair of bosses **2131** of the forward mounting section **2120** of the gearbox housing **2113**. When the blade housing **2400** is assembled to the gearbox housing **2113**, the plurality of spur gear drive teeth **2656** of the drive gear **2650** are in meshing engagement with the driven gear teeth **2330** of the rotary knife blade **2300** such that rotation of the drive gear **2650** about its axis of rotation DGR' causes rotation of the rotary knife blade **2300** about its axis of rotation R'.

To remove the blade-blade housing combination **2550** from the gearbox housing **2113**, the pair of screws **2434** are unthreaded from the threaded openings **2135** of the upper horizontal portion **2131**a of the pair of bosses **2131** of the forward mounting section **2120** of the gearbox housing **2113**. After the screws **2434** are completely unthreaded from the openings **2135**, the blade-blade housing combination **2550** will fall in a downward direction DW' away from the gearbox assembly **2112**. The blade-blade housing combination **2550** may be removed from the gearbox housing **2113** without removal of the frame body **2150** or the frame body bottom cover **2190**.

Third Exemplary Embodiment—Power Operated Rotary Knife **3100**

Overview

A third exemplary embodiment of a power operated rotary knife of the present disclosure is shown generally at **3100** in FIGS. **101-113**. The power operated rotary knife **3100** includes a handle assembly **3110**, a detachable head assembly **3111**, and a drive mechanism **3600**. As is best seen in FIG. **102**, the head assembly **3111** of the power operated rotary knife **3100** includes a gearbox assembly **3112**, a rotary knife blade **3300**, a blade housing **3400**, and a blade-blade housing support or bearing structure **3500**. The gearbox assembly **3112** includes a gearbox housing **3113** which supports a gearbox **3602** of the drive mechanism **3600**. The handle assembly **3110** includes a hand piece **3200** and a hand piece retaining assembly **3250** that secures the hand piece **3200** to the gearbox housing **3113**.

The power operated rotary knife **3100**, like the power operated rotary knife **2100** described above, is especially suited for use with small outer diameter rotary knife blades. Among the differences between the power operated rotary knife **3100** and the power operated rotary knife **2100** are the following: 1) The gearbox **3602** includes a simplified gear train **3604**, namely, the gear train **3604** comprises a single gear, namely, a pinion gear **3610**. In the power operated rotary knife **3100**, the pinion gear **3610** directly engages and drives a driven gear **3328** of the rotary knife blade **3300**. The driven gear **3328** of the rotary knife blade **3300** of the power operated rotary knife **3100** comprises a set of gear teeth **3330**. The drive gear **2650** of the gear train **2604** of the power operated rotary knife **2100** is eliminated. 2) Because the pinion gear **3610** directly drives the rotary knife blade **3300**, a set of gear teeth **3616** of a gear head **3614** of the pinion gear **3610** engage the set of gear teeth **3330** of the driven gear **3328**. Accordingly, the set of gear teeth **3330** of the rotary knife blade **3300** of the power operated rotary knife **3100** is disposed above a bearing surface **3319** formed in an outer wall **3312** of a body section **3302** of the knife blade **3300**. 3) Like the power operated rotary knife **2100**, the blade housing **3400** is secured to an L-shaped mounting pedestal **3124** of a forward mounting portion **3118** of the gearbox housing **3113**. However, in the power operated rotary knife **3100**, the frame body is eliminated. That is, there is no frame body that overlies and receives the gearbox housing as is the case, for example, with the frame body **2150** of the power operated rotary knife **2100** which receives the gearbox housing **2113**. Instead, in the power operated rotary knife **3100**, a pinion gear cover **3190** is secured to a pinion gear cover mounting surface **3132** defined by a forward wall **3140** of the gearbox housing **3113**. The pinion gear cover **3190** overlies the gear head **3614** of the pinion gear **3610** extending from a central cylindrical portion **3120** of the gearbox housing forward mounting section **3118** to protect the gear head **3614** and seal against the gearbox housing **3113** to inhibit ingress of debris into the region of the gear head **3614** of the pinion gear **3610**.

The rotary knife blade **3300** is supported for rotation with respect to the blade housing **3400** by the blade-blade housing bearing structure **3500**, similar to the blade-blade housing bearing structures **500**, **2500** of the power operated rotary knives **100**, **2100**. The blade-blade housing bearing structure **3500** includes, in one exemplary embodiment, an elongated rolling bearing strip **3502** (FIGS. **102**, **115** and **116**) disposed in an annular passageway **3504** (FIG. **116**) formed between opposing bearing surfaces facing bearing surfaces **3319**, **3459** of the rotary knife blade **3300** and the blade housing **3400**, respectfully. The rolling bearing strip includes a plurality of rolling bearings **3506**, such a ball bearings, disposed in spaced apart relation in a flexible separator cage **3508** (FIG. **116**). Alternately, the blade-blade housing bearing structure **3500** may utilize a plurality of elongated rolling bearing strips in the annular passageway **3504**. An assembled combination of the rotary knife blade **3300**, the blade housing **3400**, and the blade-blade housing bearing structure **3500** will be referred to as the blade-blade housing combination **3550** (FIG. **113-115**) and the mating bearing surfaces defined by the blade-blade housing bearing structure **3500**, the knife blade bearing surface **3319**, the blade housing bearing surface **3459**, and the blade housing plug bearing race **3442** that support the knife blade **3300** for rotation in the blade housing **3400** will be referred to as the rotary knife bearing assembly **3552** (FIGS. **108-109** and **113**). The blade-blade housing bearing structure **3500** both releasably secures the rotary knife blade **3300** to the blade housing **3400** and provides a bearing structure to support the rotary knife blade **3300** for rotation about an axis of rotation R" (FIGS. **105** and **108**). The blade-blade housing bearing structure **3500** also defines a rotational plane RP" (FIG. **108**) of the knife blade **3300** which is substantially orthogonal to the knife blade axis of rotation R".

The gearbox assembly **3112** includes a gearbox housing **3113** and the gearbox **3602**. The gearbox **3602** includes the gear train **3604** comprising, in one exemplary embodiment, a single gear, namely, the pinion gear **3610** and a bearing support assembly **3628** that supports the pinion gear **3610** for rotation within a cavity **3114** of the gearbox housing **3113**. The pinion gear **2610** is rotatably driven about a pinion gear axis of rotation PGR" (FIGS. **108** and **108**A) by a flexible shaft drive assembly (not shown). The flexible shaft drive assembly (not shown), which is part of the drive mechanism

3600, is similar to the flexible shaft drive assembly **700** of the power operated rotary knife **100**.

Other components of the drive mechanism **3600** of the power operated rotary knife **3100** include components external to the head and handle assemblies **3111**, **3110** of the power operated rotary knife **3100**. These external components include a drive motor (not shown) and the flexible shaft drive assembly which rotates the pinion gear **3610**. Such components of the power operated rotary knife **3100** are similar to the corresponding components discussed with respect to the power operated rotary knife **100**, e.g., the flexible shaft drive assembly **700** and the drive motor **800**. For brevity, components and assemblies of the power operated rotary knife **3100** that are substantially similar to corresponding components and assemblies of either of the power operated rotary knives **100** and **2100**, will not be described in detail below. It being understood by one of ordinary skill in the art that the discussion of the structure and function of the components and assemblies of the power operated rotary knives **100** and **2100**, as set forth above, is applicable to and is incorporated into the discussion of the power operated rotary knife **3100**, discussed below.

Rotary Knife Blade **3300**

In one exemplary embodiment and as seen in FIGS. **102** and **117-119**, the rotary knife blade **3300** of the power operated rotary knife **3100** is a one-piece, continuous annular structure and, specifically, is a “straight blade” style rotary knife blade. Although, it should be recognized that other rotary knife blade styles may be used in the power operated rotary knife **3100**. The rotary knife blade **3300** includes a body section **3302** and a blade section **3304** extending axially from the body **3302**. The body **3302** includes an upper end **3306** and a lower end **3308** spaced axially apart from the upper end **3306**. The body **3302** further includes an inner wall **3310** and an outer wall **3312** spaced radially apart from the inner wall **3310**. The blade section **3304** includes a blade edge **3350** defined at a distal end portion **3352** of the blade section **3304**. The blade section **3304** includes an inner wall **3354** and an axially spaced apart outer wall **3356**. A short angled portion **3358** bridges the inner and outer walls **3354**, **3356**. As can best be seen in FIGS. **117** and **119**, the blade edge **3350** is formed at the intersection of the short angled portion **3358** and the inner wall **3354**. An inner wall **3360** of the rotary knife blade **3300** is formed by the inner wall **3310** of the body **3302** and the inner wall **3354** of the blade section **3304**. In one exemplary embodiment, there is a knee or discontinuity **3360***a* of the inner wall **3360**, although it should be appreciated that, depending on the specific configuration of the rotary knife blade **3300**, the blade **3300** may be formed such that there is no discontinuity in the inner wall **3360**.

A portion **3340** of the body outer wall **3312** defines a recessed region **3318** that extends radially inwardly into the outer wall **3312**. The recessed region **3318**, in one exemplary embodiment, is generally rectangular in cross section and includes a generally horizontal or radially extending upper section **3318***a*, a generally vertical or axially extending middle section **3318***b*, and a generally horizontal or radially extending lower section **3318***c*. The rotary knife blade **3300** includes the bearing surface **3319**. In one exemplary embodiment of the power operated rotary knife **3100**, the rotary knife blade bearing surface **3319** comprises a knife blade bearing race **3320** extends radially inwardly into the middle section **3318***b* of the recessed region **3318** of the outer wall **3312**. In one exemplary embodiment, the knife bearing race **3320** defines a generally arcuate bearing face **3322** in a central portion **3324** of the race **3320**.

Each time the rotary knife blade **3300** is sharpened, material will be removed from the distal end portion **3352** and the cutting edge **3350** will move axially in an upward direction UP". Stated another way, the axial extent of both the inner and outer walls **3354**, **3356** of the blade section **3304** will decrease in extent with repeated sharpening of the blade **3300**. At such time as sharpening of the blade **3300** would impinge on the recessed region **3318** defining the bearing race **3320**, it may be said that the blade would at or near the end of its useful life. Thus, the bottom portion **3318***c* of the recessed region **3318** may be considered as the lower end **3308** of the body section and a boundary between the body and blade sections **3302**, **3304** of the rotary knife blade **3300**.

The body outer wall **3312** of the rotary blade body **3302** also defines the driven gear **3328** comprising the set of gear teeth **3330**. The set of gear teeth **3330** are formed so as to extend radially outwardly in a stepped portion **3331** of the outer wall. The stepped portion **3331** is axially above the bearing race **3320**, that is, closer to the first upper end **3306** of the body **3302**. The driven gear **3328**, in one exemplary embodiment, defines a plurality of vertically or axially oriented gear teeth **3332** which mesh with the set of spur gear teeth **3616** of the pinion gear **3610** comprising a gear drive **3640**.

Advantageously, the set of gear teeth **3330** of the knife blade driven gear **3328** are axially spaced from the upper end **3306** of the body **3302** and are axially spaced from arcuate bearing race **3320** of the body **3302**. As can be seen in FIG. **117**, a portion **3312***a* of the outer wall **3312** of the rotary knife blade body **3302** adjacent the body upper end **3306** defines an axially extending space between the upper end **3306** of the blade body **3302** and the set of gear teeth **3330** of the driven gear **3328**. Another portion **3312***b* of the outer wall **3312** of the rotary knife blade body **3302** defines an axially extending space between the set of gear teeth **3330** of the driven gear **3328** and the bearing race **3320**.

In the spur gear drive **3640**, the set of spur gear teeth **3616** of the pinion gear **3610** are located axially above the set of spur gear teeth **3330** of the driven gear **3328** of the rotary knife blade **3300**. Therefore, it is not possible for the rotary knife blade **3300** to include a driven gear projection or cap axially above the gear teeth **3616**. Instead, because of the axially extending offset between the set of gear teeth **3330** and the upper end **3306** of the blade body **3302**, space provided for a radially inwardly extending projection or cap **3456***a* of an upper end **3456** of the blade support section **3450** of the blade housing **3400**. The cap **3456***a* of the blade housing **3400** and the axially offset set of gear teeth **3300** of the rotary knife blade **3300** provide for a type of labyrinth seal that impeded ingress of pieces of meat, bone, gristle, and other debris into the driven gear **3328** of the knife blade **3300**. Except for a small clearance gap between facing surfaces of the portion **3312***a* of outer wall **3312** adjacent the upper end **3306** of the knife blade body **2302** and a terminal end **3456***b* of the blade housing cap **3456***a*, the blade housing driven gear cap **2456***a* overlies substantially an entirety of the set of gear teeth **3330**, except in a region where clearance is required for the meshing of the pinion gear **3610** and the driven gear **3328** of the rotary knife blade **3300**.

Conceptually, the respective axially upper surfaces **3330***a* of the set of gear teeth **3330**, when the knife blade **3300** is rotated, can be viewed as forming an imaginary annulus **3336** (for clarity, the imaginary annulus **3336** is shown schematically in dashed line in FIG. **118** as being spaced axially above the gear teeth **3330**). The blade housing cap **3456***a* overlies substantially all of the imaginary annulus **3336** defined by the set of gear teeth **3330**, except in a region **3420***c* (FIG. **114**) where clearance is required for the meshing of pinion gear **3610** and the driven gear **3328** of the rotary knife blade **3300**. As can be seen in FIG. **117**, the set of gear teeth **3330** of the knife blade driven gear **3328** are disposed or stepped radially outwardly from the portion **3312***a* of the outer wall **3312** adjacent the upper end **3306** of the rotary knife blade body **3302**

At the lower end **3318** of the knife blade body **3302**, the horizontal portion **3318***a* of the bearing race recessed region **3318** defines a radially outwardly extending projection or cap **3370**. The rotary knife blade cap **3370** is axially aligned with and at least partially overlies (when viewed from the distal end **3353** of the rotary knife blade **3300**) the set of gear teeth **3300**. Additionally, the rotary knife blade cap **3370** is in close proximity to and slightly axially overlaps a lower end **3458** of the blade support section **3450** of the blade housing **3400** forming a type of labyrinth seal that impeded ingress of pieces of meat, bone, gristle, and other debris into the rotary knife bearing assembly **3552**.

Blade Housing **3400**

As can best be seen in FIGS. **115-116** and **120-121**, the blade housing **3400** of the power operated rotary knife **3100** comprises a unitary or one-piece, continuous annular structure that includes the mounting section **3402** and the blade support section **3450**. In one exemplary embodiment, the blade housing is continuous about its perimeter, that is, unlike prior split-ring annular blade housings, the blade housing **3400** of the present disclosure has no split along a diameter of the housing to allow for expansion of the blade housing diameter. The blade-blade housing bearing structure **3500** secures the rotary knife blade **3300** to the blade housing **3400** and supports the blade **3300** for rotation within the blade housing **3400**. Accordingly, removal of the knife blade **3300** from the blade housing **3400** is accomplished by removing a portion of the blade-blade housing bearing structure **3500** from the power operated rotary knife **3100**.

As is best seen in FIGS. **115** and **120-121**, the mounting section **3402** of the blade housing **3400** extends radially outwardly from the blade support section **3450** and subtends an angle of approximately 120° or, stated another way, extends approximately ⅓ of the way around the circumference of the blade housing **3400**. The mounting section **3402** is both axially thicker and radially wider than the blade support section **3450**. The mounting section **3402** includes an inner wall **3404** and a radially spaced apart outer wall **3406** and a first upper end **3408** and an axially spaced apart second lower end **3410**. At forward ends **3412**, **3414** of the mounting section **3402**, there are tapered regions **3416**, **3418** (FIGS. **115** and **120**) that transition between the upper end **3408**, lower end **3410** and outer wall **3406** of the mounting section **3402** and the corresponding upper end **3456**, lower end **3458** and outer wall **3454** of the blade support section **3450**.

The mounting section **3402** defines an opening **3420** (FIGS. **115** and **120-121**) that extends radially between the inner and outer walls **3404**, **3405**. The radially extending opening **3420** is bounded by and extends between upright supports or pedestals **3422**, **3424** and an upper surface **3428***a* of a base **3428** that bridges the pedestals **3422**, **3424**. The pedestals **3422**, **3424** extend axially upwardly from the base **3428**. The base **3428** defines two axially extending apertures **3430** and the pedestals **3422**, **3424** define axially extending U-shaped recesses **3432**. The U-shaped recesses **3432** face each other and are axially aligned with the apertures **3430**. The base apertures **3430** receive a pair of threaded fasteners **3434**. The fasteners **3434** pass through the base apertures **3430** and the U-shaped pedestal recesses **3432** and thread into respective threaded openings **3130** defined in the L-shaped blade housing mounting pedestal **3124** of the gearbox housing **3113** to releasably secure the blade housing **3400** to the gearbox assembly **3112**. The threaded fasteners **3434** are prevented from falling out of their respected threaded openings **3130** by C-shaped retainer clips **3436**.

The radially extending opening **3420** of the blade housing mounting section **3402** includes a narrower upper portion **3420***a* and a wider lower portion **3420***b*. A relative width of the opening **3420** is defined by rearward facing surfaces **3438** of the pedestals **3422**, **3424** that comprise a portion of the outer wall **3406** of the mounting portion **3402** of the blade housing **3400**. The opening **3420** is sized to receive a removable blade housing plug **3440** (FIGS. **115** and **122**). The blade housing plug **2440** is removably received in the opening **3420**. When the blade housing plug **3440** is removed from the opening **3420**, access is provided to the elongated rolling bearing strip **3502** of the blade-blade housing bearing structure **3500**. When the blade housing plug **3440** is positioned in the opening **3420** and attached to the blade housing **3400** via a pair of set screws **3446** (FIG. **122**), the blade housing plug **3440** inhibits debris created during cutting/trimming operations (e.g., pieces of fat, gristle, bone, etc.) and other foreign materials from migrating to and accumulating on or adjacent the elongated rolling bearing strip **3502** of the blade-blade housing bearing structure **3500** or the driven gear **3328** of the rotary knife blade **3300**.

As can best be seen in FIG. **120**, the blade support section **3450** includes an inner wall **3452** and radially spaced apart outer wall **3454** and a first upper end **3456** and an axially spaced second lower end **3458**. The blade support section **3450** extends about the entire 360' circumference of the blade housing **3400**. The blade support section **3450** in a region of the mounting section **3402** is continuous with and forms a portion of the inner wall **3404** of the mounting section **3402**. The blade support section inner wall **3452** of the blade housing **3400** includes a bearing surface. In one exemplary embodiment of the power operated rotary knife **3100**, the blade housing bearing surface **3459** comprises a bearing race **3460** that extends radially inwardly into the inner wall **3452**. In one exemplary embodiment, a central portion **3462** of the blade housing bearing race **3460** defines a generally arcuate bearing face **3464**.

The blade support section upper end **3456** defines the driven gear cap **3456***a* that overlies the set of gear teeth **3330** of the driven gear **3328** of the rotary knife blade **3300**. As can best be seen in FIG. **117**, the blade housing bearing race **3460** is axially spaced from both the upper and lower ends **3456**, **3458** of the blade support section **3450**. Specifically, there is a portion **3466** of the inner wall **3452** of the blade support section **3450** extending axially between the blade housing bearing race **3460** and the cap **3456***a* and there is a portion **3468** of the inner wall **3452** extending axially between the blade support section lower end **3458** and the bearing race **3460**.

As is best seen in FIGS. **105** and **121**, the right tapered region **3416** (as viewed from a front of the power operated rotary knife **3100**) of the blade housing mounting section **3402** includes a port **3480** for injecting cleaning fluid for cleaning the blade housing **3400** and the rotary knife blade **3300** during a cleaning process. The cleaning port **2480** passes from an entry opening **3481** in the outer wall **3406** of the mounting section right tapered region **3416** to an exit opening **3482** in the inner wall **3404** of the mounting section **3402**. The exit opening **3482** (FIG. **121**) defined by the port **3480** is in fluid communication with the blade housing bearing race **3460** and the inner wall portion **3466** of the blade support section **3450** above the bearing race **3460**.

Blade Housing Plug **3440**

As can best be seen in FIGS. **115** and **122**, the blade housing plug **3440** includes an upper end **3440***a*, an axially spaced apart a lower end **3440***b*, an inner wall **3440***c* and a radially spaced apart outer wall **3440***d*. The blade housing plug **3440** also includes a pair of stepped shoulders **3441** formed in opposite sides **3440***e* of the blade housing plug **3440**. The stepped shoulder **3441** bear against the pedestals **3422**, **3424** of the mounting section **3402** to secure the blade housing plug **3440** to the blade housing **3400** when the set screws **3446** pass through respective openings **3447** in the blade housing plug **3440** and are tightened against the blade housing base upper surface **3428***a*. The inner wall **3440***c* defines an arcuate bearing race **3442** that continues the bearing race **3460** of the blade housing blade section inner wall **3452**. The radially inner wall **3440***c* of the blade housing plug **3440** defines a portion of the blade housing bearing race **3460** such that the blade housing bearing race **3460** is continuous about substantially the entire 360° circumference of the blade support section **3450**.

The upper end **3440***a* of the blade housing plug **3440** defines a first arcuate recess **3443** (FIG. **122**) adjacent the inner wall **3452** that provides clearance for the gear head **3614** of the pinion gear **3610**. A portion of the upper end **3440***a* on one side of the arcuate recess **3443** includes a radially inwardly extending driven gear cap **3444** that continues the driven gear cap **3456***a* of the blade support section **3450**. However, because the spur gear drive **3640** requires that the pinion gear **3610** be located axially above the set of spur gear teeth **3330** of the driven gear **3328** of the rotary knife blade **2300**, the clearance region **3420***c* (FIG. **114**) of the mounting section opening **3420** must be provided for the meshing engagement of the set of gear teeth **3616** of the pinion gear with the driven gear **3328** of the rotary knife blade **3300**. Accordingly, as can best be seen in FIG. **114**, the driven gear cap **3444** only extends a portion of the way across the upper end **3440***a* of the blade housing plug **3440** between the right and left sides **3440***e*, **3440***f* of the blade housing plug **3440** such that the clearance region **3420***c* is provided for the meshing engagement of pinion gear **3610** and the rotary knife blade driven gear **3330**. The clearance region **3420***c* corresponds to the arcuate region in FIG. **114** where the driven gear **3328** of the rotary knife blade **3300** is visible.

The upper end **3440***a* of he blade housing plug **3440** also includes a second larger arcuate recess **3445** that functions as a seating surface for engagement with a radial seating surface **3120***c* (FIGS. **124-126**) of the forward mounting section **3118** of the gearbox housing **3113** when the blade housing **3400** is affixed to the gearbox housing **3113**. When the blade housing plug **3440** is installed in the opening **3420** of the mounting section **3402**, the outer wall **3440***d* of the blade housing plug **3440** is flush with the outer wall **3406** of the blade housing mounting section **3402** and forms part of a vertical planar seating surface the outer wall **3406** that engages a vertical planar seating surface **3128** (FIG. **126**) of the L-shaped blade housing mounting pedestal **3124** of the gearbox housing **3113** when the blade housing **3400** is secured to the gearbox housing **3113**. Similarly, when the blade housing plug **3440** is installed in the opening **3420** of the mounting section **3402**, the upper end **3440***a* of the blade housing plug **3440** is flush with the upper end **3408** of the blade housing mounting section **3402** and forms part of a horizontal planar seating surface that engages a horizontal planar seating surface **3126** (FIG. **124**) of the L-shaped blade housing mounting pedestal **3124** of the gearbox housing **3113** when the blade housing **3400** is secured to the gearbox housing **3113**.

Gearbox Assembly **3112**

As is best seen in FIGS. **102**, **108** and **123-126**, the gearbox assembly **3112** of the power operated rotary knife **3100** includes the gearbox housing **3113** and the gearbox **3602**, which is supported by the gearbox housing **3113**. The gearbox **3602** comprises the gear train **3604**, namely, the pinion gear **3610** and the bearing support assembly **3628**. As can best be seen in FIG. **108**A, the pinion gear bearing support assembly **3638**, in one exemplary embodiment, includes first and second spaced apart ball bearing assemblies **3630**, **3632** that are supported within the throughbore **3115** of the gearbox housing **3113**. The first and second ball bearing assemblies **3630**, **3632** support the pinion gear **3610** for rotation about its axis of rotation PGR", which is substantially coincident with the longitudinal axis LA" of the handle assembly **3110**.

As is best seen in FIGS. **128** and **129**, the pinion gear **3610** includes the gear head **3614** and an input shaft **3612** extending rearwardly from the gear head **3614**. A radially outwardly extending collar **3627** (FIG. **108**A) separates the gear head **3614** and the input shaft **3612**. Supporting the pinion gear **3610** for rotation in the gearbox housing **3113** are the first ball bearing assembly **3630**, which is disposed about an end portion **3624** of the pinion gear input shaft **3612** adjacent the collar **3628**, and the second ball bearing assembly **3632**, which is disposed about an opposite end portion **3626** of the pinion gear input shaft **3612**.

The gear head **3614** of the pinion gear defines the set of spur gear teeth **3616**. The input shaft **3612** includes a central opening **3618** (FIGS. **108**A and **129**). An inner surface **3620** of the input shaft central opening **3618** defines a female socket or fitting **3622**. The female fitting **3622** in engaged by a mating male drive fitting of the flexible shaft drive assembly (not shown) to rotate the pinion gear **3610**, which, in turn, rotates the rotary knife blade **3300** via the spur gear drive **3640**.

Gearbox Housing **3113**

The gearbox housing **3113** includes a generally cylindrical rearward section **3116** (in the rearward direction RW" away from the blade housing **3400**) and an enlarged forward mounting section **3118** (in the forward direction FW" toward the blade housing **3400**). The gearbox housing **3113** includes the gearbox cavity or opening **3114** (FIG. **126**) which defines the throughbore **3115** extending through the gearbox housing **3113** from a forward end **3140** to a rearward end **3142** of the gearbox **3113**. The throughbore **3115** extends generally along the handle assembly longitudinal axis LA" and provides a cavity for receiving the pinion gear **3610** and its associated support bearing assembly **3638**.

As can best be seen in FIG. **126**, an inner surface **3150** of the gearbox housing **3113** defining the throughbore **3115**, when viewed along the longitudinal axis LA', includes a generally cylindrical central region **3180**. The cylindrical central region **3180** includes recessed regions **3184**, **3186** that are axially spaced apart with respect to the pinion gear axis of rotation PGR". The recessed regions **3184**, **3186** receive respective outer races of the first and second ball bearing assemblies **3630**, **3632** and hold the respective ball bearing assemblies in place.

The inner surface **3150** of the gearbox housing **3113** also includes a threaded region **3156** adjacent the rearward end **3142** of the gearbox housing **3113**. The internal threaded region **3156**, which is part of the cylindrical rearward section **3116** of the gearbox housing **3113**, receives mating external threads **3258** of a frame screw **3250** of a hand piece retaining assembly **3250** (described below) to secure the hand piece **3200** to the gearbox housing **3113**.

As can best be seen in FIGS. **102** and **124-126**, the forward mounting section **3118** of the gearbox housing **3113** includes a central portion **3120** that, in effect, continues a reduced diameter portion **3116***a* of the cylindrical rearward section **3116** of the gearbox housing **3113** and defines a portion of the gearbox cavity **3114** and the throughbore **3115**. The central cylindrical portion **3120** includes an upper section **3120***a* that is coextensive with the forward end **3140** of the gearbox housing **3113** and a lower section **3120***b* that is recessed from the forward end **3140**. The forward mounting section **3118** additionally includes an outwardly and downwardly extending flange **3122** that provides seating or mounting surfaces for: 1) the blade-blade housing combination **3550**; and 2) the pinion gear cover **3190**. The extending flange **3122** defines the L-shaped blade housing mounting pedestal **3124**. The L-shaped blade housing mounting pedestal **3124** comprises the first horizontal planar seating or mounting surface **3126** and a second vertical planar seating or mounting surface **3128**. The horizontal planar seating surface **3126** is substantially parallel to the axis of rotation R" of the rotary knife blade **3300** and includes a pair of threaded openings **3130** (FIG. **125**).

To removably attach the blade-blade housing combination **3550** to the gearbox housing **3113**, the upper end **3408** of the mounting section **3402** of the blade housing **3400** is aligned adjacent the horizontal planar seating surface **3126** of the L-shaped blade housing mounting pedestal **3124** and the outer wall **3406** of the blade housing mounting section **3402** is aligned adjacent the vertical planar seating surface **3128**. Specifically, the upper end **3408** of the blade housing mounting section **3402** and the upper end **3440***a* of the blade housing plug **3440** are in contact with the horizontal planar seating surface **3126** of the L-shaped blade housing mounting pedestal **3124**. Additionally, a rearward surface **3428***b* of the base **3428** of the blade housing mounting section **3402** and the outer wall **3440***d* of the blade housing plug **3440** are in contact with the vertical planar seating surface **3128** of the L-shaped blade housing mounting pedestal **3124**.

The pair of fasteners **3434** is positioned to pass through respective openings **3430** of the base **3428** of the blade housing mounting section **3402** and are threaded into respective ones of the threaded openings **3130** of the horizontal seating surface **3126** and tightened until snug. When the blade housing **3400** is assembled to the gearbox housing **3113**, the set of spur gear teeth **3616** of the pinion gear **3610** are in meshing engagement with the driven spur gear teeth **3330** of the rotary knife blade **3300** such that rotation of the pinion gear **3610** about its axis of rotation PGR" causes rotation of the rotary knife blade **3300** about its axis of rotation R". Further, as can best be seen in FIG. **105**, when assembled, a lower portion **3128***a* of the vertical planar seating surface **3128** extends in a downward direction DW" below the respective heads of the pair of fasteners **3434**.

As can best be seen in FIGS. **123** and **124**, the forward end **3140** of the gearbox assembly **3113** defines a generally planar pinion gear mounting or seating surface **3132**. The pinion gear mounting surface **3132**, which is generally vertical and substantially parallel to the second vertical planar seating surface **3128** of the L-shaped blade housing mounting pedestal **3124**, is adapted to releasably receive the pinion gear cover **3190** that overlies a portion of a gear head **3614** of the pinion gear **3610**.

The planar pinion gear mounting surface **3132** comprises a central arcuate region **3134** and a pair of radially extending wing regions **3136** (FIG. **124**) that extend outwardly from the central arcuate region **3134**. Each of the extending wing regions **3136** includes a threaded opening **3138**. Each of the threaded openings **3138** receives a respective threaded fastener **3170** that secure the pinion gear cover **3190** to the pinion gear mounting surface **3132**.

Pinion Gear Cover **3190**

As can best be seen in FIGS. **124** and **127**, the pinion gear cover **3190** includes a forward or front surface **3190***a* and a rearward or back surface **3190***b* and further includes a central region **3194** and a pair of extending wing regions **3198**. Each of the extending wing regions **3198** includes an opening **3192**. The threaded fasteners **3170** pass through respective openings **3192** of the pinion gear cover **3190** and thread into the threaded openings **3138** in the pinion gear mounting surface **3132** to secure the pinion gear cover **3190** to the gearbox housing **3113**.

As is seen in FIG. **127**, the front surface **3190***a* of the pinion gear cover **3190** in the central region **3194** is recessed or concave (bowed inwardly) such that the central region **2194** conforms generally to a radius of curvature of the inner wall **3360** of the rotary knife blade **3300**. The front surface **3190***a* of the pinion gear cover **3190** in the extending wing regions **3198** is generally planar. An upper domed region **3196** (FIG. **124**) of the pinion gear cover **3190** overlies and conforms to the central arcuate surface **3134** of the pinion gear cover mounting surface **3132** of the gearbox housing **3113**, while the extending wing regions **3198** of the pinion gear cover **3190** overlie and conform to the radially outwardly extending regions **3136** of the pinion gear cover mounting surface **3132**.

When the rotary knife **3100** is in assembled condition, a bottom surface **3190***c* of the pinion gear cover **3190** (FIG. **105**) is in close proximity to or contacts the upper end **3408** of the blade housing mounting section **3402** and is in close proximity to the upper end **3306** of the rotary knife blade body **3302**. Thus, the pinion gear cover **3190** inhibits ingress of debris into a region of the gear head **3614** of the pinion gear **3610** and the driven gear **3328** of the rotary knife blade **3300**. Additionally, the bottom surface **3190***c* of the pinion gear cover **3190** functions as a cap positioned over a portion of the clearance region **3420***c* (FIG. **114**) of the opening **3420** of the blade housing **3400** to further inhibit entry of debris into the knife blade driven gear **2328** in the clearance region **3420***c*.

Handle Assembly **3110**

As is best seen in FIG. **102**, the handle assembly **3110** of the power operated rotary knife **3100** includes the hand piece **3200** and the hand piece retaining assembly **3250**. The handle assembly **3110** extends along a longitudinal axis LA" (FIGS. **101** and **108**), which is substantially orthogonal to and intersects the rotary knife blade axis of rotation R". As best seen in FIGS. **102** and **108**, the hand piece **3200** includes an outer gripping surface **3202** and an inner surface **3204**. The inner surface **3204** defines a throughbore **3206** that extends along the longitudinal axis LA" between a front wall **3214** and an enlarged proximal end **3210** of the hand piece **3200**. The inner surface **3204** of the hand piece **3200** defined a plurality of splines **3212** adjacent the front wall **3214** and a stepped shoulder **3408** rearward or proximal of the plurality of splines **3212**.

As can be seen in FIG. **108**, the enlarged proximal end **3210** of the hand piece **3200** includes a drive shaft latching assembly **3275**, similar in structure to the drive shaft latching assemblies **275** and **2275** of the power operated rotary knives **100** and **2100**, respectively, for releasably securing a flexible shaft drive assembly (similar to the shaft drive assembly **700**) to the handle assembly **3110**. The principal difference between the drive shaft latching assembly **3275** of the power operated rotary knife **3100** and the drive shaft latching assemblies **275**, **2275** of the power operated rotary knifes **100**, **2100** is that the drive shaft latching assembly **3275** is disposed in the enlarged proximal end **3210** of the hand piece **3200**, as opposed to being disposed in the enlarged proximal end portion **260** of the elongated central core **252** of the hand piece retaining assembly **250**, as was the case with the power operated rotary knife **100**.

The hand piece retaining assembly **3250** of the power operated rotary knife **3100** includes the frame screw **3252** and a coil spring **3270** extending in a rearward direction RW" from the frame screw **3252**. The frame screw **3252** includes the threaded outer surface **3258** at a distal end **3256** of the frame screw **3252**, As is best seen in FIG. **108**, the threaded outer surface **3258** of the frame screw **3252** threads into a threaded interior region **3156** of a cylindrical rearward section **3116** of the gearbox housing **3113** to releasably secure the hand piece **3200** to the gearbox housing **3113**. When the frame screw **3252** is threaded into the threaded interior region **3156** of the gearbox housing **3113**, an outwardly extending central collar **3254** of the frame screw **3252** bears against the stepped shoulder **3208** of the inner surface **3204** of hand piece **3200** to prevent the hand piece **3200** from moving in the rearward direction RW". At the same time, the front wall **3214** of the hand piece **3200** bears against a shoulder **3164** of the cylindrical rearward section **3116** of the gearbox housing **3113** to prevent the hand piece **3200** from moving in the forward direction FW". The plurality of splines **3212** of the inner surface **3204** of the hand piece **3200** interfit with a plurality of splines **3162** formed on an outer surface **3160** of the gearbox housing **3113** to allow the hand piece **3200** to be position in any desired rotational orientation about the handle assembly longitudinal axis LA" with respect to the gearbox housing **3113**.

Fourth Exemplary Embodiment—Power Operated Rotary Knife **4100**

Overview

A fourth exemplary embodiment of a power operated rotary knife of the present disclosure is shown generally at **4100** in FIGS. **130-139**. The power operated rotary knife **4100** includes a handle assembly **4110**, a detachable head assembly **4111**, and a drive mechanism **4600**. As is best seen in FIG. **131**, the head assembly **4111** of the power operated rotary knife **4100** includes a gearbox assembly **4112**, a rotary knife blade **4300**, a blade housing **4400**, and a blade-blade housing support or bearing structure **4500**. The knife blade **4300** rotates about an axis of rotation R''' within the blade housing **4400**.

The rotary knife blade **4300** is supported for rotation with respect to the blade housing **4400** by the blade-blade housing bearing structure **4500**, similar to the blade-blade housing bearing structures **500**, **2500**, **3500** of the power operated rotary knives **100**, **2100**, **3100**. The blade-blade housing bearing structure **4500** includes, in one exemplary embodiment, an elongated rolling bearing strip **4502** (FIGS. **131-132** and **141-142**) disposed in an annular passageway **4504** (FIG. **142**) formed between opposing bearing surfaces **4319**, **4459** of the rotary knife blade **4300** and the blade housing **4400**, respectfully. The rolling bearing strip **4502** includes a plurality of rolling bearings **4506**, such a ball bearings, disposed in spaced apart relation in a flexible separator cage **4508** (FIG. **132**). Alternately, the blade-blade housing bearing structure **4500** may utilize a plurality of elongated rolling bearing strips in the annular passageway **4504** disposed in head-to-tail or spaced apart relationship.

An assembled combination of the rotary knife blade **4300**, the blade housing **4400**, and the blade-blade housing bearing structure **4500** will be referred to as the blade-blade housing combination **4550** (FIGS. **140** and **141**) and the mating bearing surfaces defined by the blade-blade housing bearing structure **4500**, the knife blade bearing surface **4319**, the blade housing bearing surface **4459**, and the blade housing plug bearing race **4446** that support the knife blade **4300** for rotation in the blade housing **4400** will be referred to as the rotary knife bearing assembly **4552** (FIGS. **139**A and **142**). The blade-blade housing bearing structure **4500** both releasably secures the rotary knife blade **4300** to the blade housing **4400** and provides a bearing structure to support the rotary knife blade **4300** for rotation about an axis of rotation R''' (FIGS. **105** and **108**). The blade-blade housing bearing structure **4500** also defines a rotational plane RP''' (FIG. **139**) of the knife blade **4300** which is substantially orthogonal to the knife blade axis of rotation R'''.

The gearbox assembly **4112** includes a gearbox housing **4113** which supports a gearbox **4602** of the drive mechanism **4600**. The gearbox assembly **4112** also includes a frame body **4150** which receives the gearbox housing **4113** and a frame body bottom cover **4190** which is affixed to the frame body **4150** to seal the gearbox housing **4113** within the frame body **4150**. The handle assembly **4110**, which extends along a longitudinal axis LA''', which is substantially orthogonal to and intersects the knife blade axis of rotation R''', includes a hand piece **4200** and a hand piece retaining assembly **4250** that secures the hand piece **4200** to the gearbox housing **4113**. The handle assembly **4110** also includes a drive shaft latching assembly **4275** disposed in an enlarged proximal end **4210** of the hand piece **4200**. The handle assembly **4110**, hand piece retaining assembly **4250** and the drive shaft latching assembly **4275** are similar to the handle assembly **3110**, the hand piece retaining assembly **3250**, and the drive shaft latching assembly **3275** of the power operated rotary knife **3100**.

The gearbox **4602** of the power operated rotary knife **4100** includes a gear train **4204** which, similar to the gear trains **604**, **2604** of the power operated rotary knives **100**, **2100**, comprises a pinion gear **4610** and a drive gear **4650**. The drive gear **4650** is a double gear which includes a first bevel gear **4652** which is driven by the pinion gear **4610**. The drive gear **4650** also includes a second spur gear **4654** which engages a drive gear **4328** of the rotary knife blade **4300** to rotate the rotary knife blade **3300** about the knife blade axis of rotation R''' via a spur gear drive.

The power operated rotary knife **4100**, like the power operated rotary knife **100** described above, is especially suited for use with larger outer diameter rotary knife blades. Among the differences between the power operated rotary knife **4100** and the power operated rotary knife **100** are the following: 1) In the power operated rotary knife **4100**, a set of gear teeth **4330** of the driven gear **4328** of the annular rotary knife blade **4300** is disposed above the bearing surface **4319** formed in an outer wall **4312** of a body section **4302** of the knife blade **4300**. 2) Like the power operated rotary knife **100**, the blade housing **4400** of the power operated rotary knife **4100** is secured to a mounting pedestal **4152** of the frame body **4150**. However, in the power operated rotary knife **100**, the frame body **150** received the gearbox housing **113** in the cavity **155** of the frame body **150** as the gearbox housing **113** was moved in the forward direction FW along the longitudinal axis LA with respect to the frame body **150**, somewhat akin to a dresser drawer being slid into a dresser. The frame body **150** surrounded both the top and the bottom of the gearbox housing **113**.

By contrast, in the power operated rotary knife **4100**, the structural relationship between the frame body **4150** and the gearbox housing **4113** is generally similar to the structural relationship between the frame body **2150** and the gearbox housing **2113** of the power operated rotary knife **2100**. Specifically, in the power operated rotary knife **4100**, the frame body **4150** defines a socket **4156** (FIG. **150**) and has an open bottom wall **4182**. This configuration allows the frame body **4150** to be moved in a downward direction DW''' (FIG. **148**) orthogonal to the handle assembly longitudinal axis LA''' to slide over the gearbox housing **4113**. A thin frame body bottom cover **4190** is secured to the frame body **4150** to cover, protect, and support the gearbox housing **2113**.

Other components of the drive mechanism **4600** of the power operated rotary knife **4100** include components external to the head and handle assemblies **4111**, **4110** of the power operated rotary knife **4100**. These external components include a drive motor (not shown) and the flexible shaft drive assembly which rotates the pinion gear **4610**. Such components of the power operated rotary knife **4100** are similar to the corresponding components discussed with respect to the power operated rotary knife **100**, e.g., the flexible shaft drive assembly **700** and the drive motor **800**. For brevity, components and assemblies of the power operated rotary knife **4100** that are substantially similar to corresponding components and assemblies of any of the power operated rotary knives **100**, **3100** and **2100**, will not be described in detail below. It being understood by one of ordinary skill in the art that the discussion of the structure and function of the components and assemblies of the power operated rotary knives **100**, **2100** and **3100**, as set forth above, is applicable to and is incorporated into the discussion of the power operated rotary knife **4100**, discussed below.

Rotary Knife Blade **4300**

As best seen in FIGS. **143** and **144**, the rotary knife blade **4300** of the power operated rotary knife **4100** is continuous annular and comprises a unitary or one-piece annular structure. The rotary knife blade **4300** is a "flat style" rotary knife blade, but, it should be understood, that the power operated rotary knife **4300** may be used with a variety of rotary knife blade styles and sizes, depending on the specific cutting or trimming application. The rotary knife blade **4300** includes a body **4302** and a blade section **4304** extending axially from the body **4302**. The knife blade body **4302** includes an upper end **4306** and a lower end **4308** spaced axially apart from the upper end **4306**. The body **4302** further includes an inner wall **4310** and an outer wall **4312** spaced radially apart from the inner wall **4310**. The body outer wall **4312** defines a knife blade bearing surface. In one exemplary embodiment of the power operated rotary knife **4100**, the knife blade bearing surface **4319** comprises a knife blade bearing race **4320** (best seen in FIG. **144**) that extends radially inwardly into the outer wall **4312**. In one exemplary embodiment, the knife bearing race **4320** defines a generally arcuate bearing face **4322** in a central portion **4324** of the race **4320**.

The body outer wall **4312** of the rotary blade body **4302** also defines a driven gear **4328** comprising a set of gear teeth **4330** formed so as to extend radially outwardly in a stepped portion **4331** of the outer wall. The stepped portion **4331** is axially above the bearing race **4320**, that is, closer to the first upper end **4306** of the body **4302**. The driven gear **4328**, in one exemplary embodiment, defines a plurality of involute spur gear teeth **4332**.

Advantageously, the set of gear teeth **4330** of the knife blade driven gear **4328** are axially spaced from the upper end **4306** of the body **4302** and are axially spaced from arcuate bearing race **4320** of the body **4302**. In order to minimize the ingress of pieces of meat, bone and other debris into the driven gear **4328** of the knife blade **4300**, a radially outwardly extending projection or cap **4334**. As can best be seen in FIG. **144**, the cap **4334** is generally rectangular in cross section and is axially aligned with and overlies the driven gear **4328**, when viewed from the upper end **4306** of the blade body **4302**. An upper surface of the driven gear cap **4334** defines the upper end **4306** of the knife blade body **4302** and an angled surface **4335** of the cap **4334** defines part of the outer wall **4312** of the body **4302**. Conceptually, the respective radially outer surfaces **4330***a* of the set of gear teeth **4330**, when the knife blade **4300** is rotated, can be viewed as forming an imaginary cylinder **4336** (shown schematically in FIG. **144**). The driven gear cap **4334** extends slightly radially outwardly of the imaginary cylinder **4336** defined by the set of gear teeth **4330**. Additionally, as can also be seen in FIG. **144**, the set of gear teeth **4330** of the knife blade driven gear **4328** are disposed or stepped radially outwardly from a portion **4340** of the outer wall **4312** that defines the knife blade bearing race **4320**.

In the rotary knife blade **4300**, the second end **4308** of the knife blade body **4302** transitions radially inwardly between the body **4302** and the blade section **4304**. The second end **4308** of the body **4302** is defined by a radially inwardly extending step or shoulder **4308***a*. The blade section **4304** extends from the second end **4308** of the body **4302** and includes a blade cutting edge **4350** at an inward end **4352** of the blade section **4304**. As can be seen, the blade section **4304** includes an inner wall **4354**, a radially spaced apart outer wall **4356** and a bridging portion **4358** between the inner and outer walls **4354**, **4356**.

The rotary knife blade body inner wall **4310** and the blade section inner wall **4354** together form a continuous knife blade inner wall **4360** that extends from the body upper end **4306** to the cutting edge **4350**. The knife blade inner wall **4360** is generally frustoconical in shape, converging in a downward direction (labeled DW''' in FIG. **144**). The knife blade inner wall **4360** defines a cutting opening CO''' (FIG. **143**) of the power operated rotary knife **4100**.

Blade Housing **4400**

In one exemplary embodiment and as best seen in FIGS. **140-141** and **145-147**, the blade housing **4400** of the power operated rotary knife **4100** is continuous annular and comprises a unitary or one-piece annular structure. The blade housing **4400** includes a mounting section **4402** and a blade support section **4450**.

The blade housing mounting section **4402** includes an inner wall **4404** and a radially spaced apart outer wall **4406** and a first upper end **4408** and an axially spaced apart second lower end **4410**. At forward ends **4412**, **4414** of the mounting section **4402**, there are tapered regions **4416**, **4418** that transition between the upper end **4408**, lower end **4410** and outer wall **4406** of the mounting section and the corresponding upper end, lower end and outer wall of the blade support section **4450**. The blade housing mounting section **4402** includes two mounting inserts **4420** (FIG. **132**) that extend between the upper and lower ends **4408**, **4410** of the mounting section **4402**. The mounting inserts **4420** define threaded openings **4422**. When the mounting insert threaded openings **4420** are engaged by respective threaded fasteners **4170** extending through threaded openings **4172** of arcuate arms **4160**, **4162** of the frame body **4150**, the blade housing **4400** is releasably secured to the gearbox assembly **4112**. The mounting section **4402** further includes an opening **4424** that extends radially between the inner and outer walls **4404**, **4406**. As can best be seen in FIGS. **146** and **147**, the opening **4424** includes a narrower upper portion **4426** and a wider lower portion **4428**.

The narrower upper portion **4426** of the opening **4424** is sized to receive the spur gear **4654** of the drive gear **4650** of the gear train **4604**. The gear teeth **4656** of the spur gear **4654** mesh with the set of gear teeth **4330** of the knife blade driven gear **4328** to rotate the knife blade **4300** with respect to the blade housing **4400**. The wider lower portion **4428** of the opening **4424** is sized to receive a blade housing plug **4430** (FIGS. **131-132**, **140** and **145**). The blade housing plug **4430** is removably secured to the blade housing **4400** by two screws **4432** (FIG. **132**). The screws **4432** pass through a pair of countersunk openings **4434** that extend from the upper end **4408** of the mounting section **4402** to the lower portion **4428** of the opening **4424** and engage a pair of aligned threaded openings **4438** of the blade housing plug **4430**.

The blade housing **4400** also includes a semicircular recess **4440** (FIG. **140**) in the outer wall **4406**. The semicircular recess **4440** extends radially inwardly almost to the inner wall **4404** and provides clearance for the axially oriented bevel gear **4652** of the drive gear **4650**. The blade housing plug **4430** includes a recess **4442** in an upper surface **4443** of the plug **4430** to provide clearance for the spur gear **4654** of the drive gear **4650**. A cutout **4444** in a radially outer wall **4445** of the blade housing plug **4430** provides for clearance for a fastener **4672** of a ball bearing support assembly **4660** of the gearbox **4602** that rotatably supports the drive gear **4650**.

As can best be seen in FIGS. **142** and **145-147**, the blade support section **4450** includes an inner wall **4452** and radially spaced apart outer wall **4454** and a first upper end **4456** and an axially spaced second lower end **4458**. The blade support section **4450** extends about the entire 360° circumference of the blade housing **4400**. The blade support section **4450** in a region of the mounting section **4402** is continuous with and forms a portion of the inner wall **4404** of the mounting section **4402**, that is, the portion between the lines labeled IWBS''' in FIG. **147**. The blade support section inner wall **4452** defines a bearing surface, In one exemplary embodiment of the power operated rotary knife **4100**, the blade housing bearing surface **4459** comprises a bearing race **4460** that extends radially inwardly into the inner wall **4452**. In one exemplary embodiment, a central portion **4462** of the blade housing bearing race **4460** defines a generally arcuate bearing face **4464**. A portion of the radially inner wall **4447** (FIG. **145**) of the blade housing plug **4430** defines a blade housing bearing race **4446** that is aligned with and continues the blade housing bearing race **4460** such that the blade housing bearing race **4460** is substantially continuous about the entire 360° circumference of the blade support section **4450**.

As is best seen in FIG. **142**, the blade support section inner wall **4452** of the blade housing **4400** includes a first radially outwardly extending ledge **4470** that is located axially above the blade housing bearing race **4460**. The blade support section inner wall **4452** also includes a second radially outwardly extending angled ledge **4472** that is axially spaced above the first radially outwardly extending ledge **4470**. The first and second ledges **4470**, **4472** provide a seating regions for a bottom surface **4362** of the set of gear teeth **4330** and the angled surface **4335** of the driven gear cap **4334**, respectively, to support the knife blade **4300** when the knife blade **4300** is positioned in the blade housing **4400** from axially above and the rolling bearing strip **4502** of the blade-blade housing bearing structure **4500** has not been inserted into a passageway **4504** (FIG. **142** between the rotary knife blade **4300** and the blade housing **4400**. Of course, it should be understood that without insertion of the rolling bearing strip **4502** into the passageway **4504** between opposing arcuate bearing faces **4322**, **4464** of the rotary knife blade **4300** and the blade housing **4400**, if the power operated rotary knife **4100** were turned upside down, that is, upside down from the orientation of the power operated rotary knife **4100** shown, for example, in FIG. **130**, the rotary knife blade **4300** would fall out of the blade housing **4400**. When the rolling bearing strip **4502** of the blade-blade housing bearing structure **4500** is inserted in the passageway **4504**, as schematically depicted in FIG. **142**, there is a small operating clearance between the angled ledge **4472** of the inner wall **4452** of the blade housing blade support section **4450** and the angled surface **4335** of the outer wall **4312** of the rotary knife blade body **4302**. The proximity and shape of the rotary blade angled surface **4335** and the blade housing angled ledge **4472** from a type of labyrinth seal to inhibit ingress of debris into the region of the driven gear **4328** of the knife blade **4300**. As is best seen in FIGS. **145-147**, the tapered region **4416** of the blade housing mounting section **4402** includes a port **4480** for injecting cleaning fluid for cleaning the blade housing **4400** and the knife blade **4300** during a cleaning process. The port **4480** passes from an entry opening **4481** in the mounting section outer wall **4406** to an exit opening **4482** in the mounting section inner wall **4404**. The exit opening **4482** is in fluid communication with the blade housing bearing race **4460**.

Gearbox Assembly **4112**

The gearbox assembly **4112** is part of the head assembly **4111** of the power operated rotary knife **4100** and includes the gearbox **4602**, the gearbox housing **4113**, the frame body **4150** and the frame body bottom cover **4190**. The gearbox **4602** is supported in the gearbox housing **4113**, while the gearbox housing **4113** is received and supported in the combination of the frame body **4150** and the frame body bottom cover **4190**. The blade-blade housing combination **4550** is releasably secured to an arcuate mounting pedestal **4152** of the frame body **4150** to complete the head assembly **4111** of the power operated rotary knife **4100**.

The gearbox **4602** comprises a gear train **4604** and associated bearing support assemblies for rotatably supporting gears of the gear train **4604**. The gear train **4604** of the power operated rotary knife **4100** is similar to the gear trains **604**, **2604** of the power operated rotary knifes **100**, **2100** in that the gear train **4604** includes a pinion gear **4610** and a drive gear **4650**. A pinion gear bearing support assembly **4628** of the power operated rotary knife **4100** that supports the pinion gear **4610** for rotation about its axis of rotation PGR''' (FIG. **139**A) is, in one exemplary embodiment, different from the pinion gear bearing support assemblies **628** and **2628** of the power operated rotary knives **100**, **2100**. By contrast, a drive gear bearing support assembly **4660** of the power operated rotary knife **4100** that supports the drive gear **4650** for rotation about its axis of rotation DOW'' is, in one exemplary embodiment, similar to the drive gear bearing support assemblies **660**, **2660** of the power operated rotary knives **100**, **2100**.

The pinion gear **4610** includes a gear head **4614** comprising a set of bevel gear teeth **4616** and an input shaft **4612** extending rearwardly from the gear head **4614**. The gear head **4614** of the pinion gear **4610** engages the drive gear **4650** to drive the annular rotary knife blade **4300**. The gearbox drive gear **4650** is a double gear that includes an upper, vertically or axially oriented bevel gear **4652** and a lower, horizontally or radially oriented spur gear **4654**. The drive gear upper bevel gear **4652** engages and is rotatably driven by the set of bevel gear teeth **4616** of the gear head **4614** of the pinion gear **4610**. The drive gear lower spur gear **4654** defines a plurality of drive gear teeth **4656** that are mating involute gear teeth that mesh with the involute gear teeth **4332** of the rotary knife blade driven gear **4328** to rotate the rotary knife blade **4300**. This gearing combination between the drive gear **4650** and the rotary knife blade **4300** defines a spur gear involute gear drive **4658** (FIG. **139**A) to rotate the knife blade **4300**.

The pinion gear bearing support assembly **4628**, in one exemplary embodiment, includes first and second rolling or ball bearing assemblies **4630**, **4632** which are axially spaced apart with respect to the longitudinal axis LA'". The pair of axially spaced apart rolling or ball bearing assemblies **4630**, **4632** is lodged in the gearbox housing throughbore **4115**. As is best seen in FIG. **139**A, the first ball bearing assembly **4630** is disposed around an end portion **4634** of the pinion gear input shaft adjacent a stepped shoulder **4617** of the gear head **4614** and the second ball baring assembly **4632** is disposed around an opposite end portion **4636** of the pinion gear input shaft **4612**.

The drive gear **4650**, like the drive gear **650** of the power operated rotary knife **100**, is a double gear with an axially aligned first gear **4652** and an integral second gear **4654**, the drive gear **4650** rotating about the drive gear axis of rotation DGR'" (FIG. **139**A). The drive gear axis of rotation DGR'" is substantially parallel to the rotary knife blade axis of rotation R'" and is substantially orthogonal to and intersects the pinion gear axis of rotation PGR'" and the handle assembly longitudinal axis LA'". The first gear **4652** of the drive gear **4650** is a bevel gear and includes a set of bevel gear teeth **4653** that mesh with the set of bevel gear teeth **4616** of the gear head **4614** of the pinion gear **4610**. The second gear **4654** comprises a spur gear including a set of involute gear teeth **4656**. The spur gear **4654** of the drive gear **4650** and the driven gear **4328** of the knife blade **4300** comprise an involute spur gear drive, having respective axes of rotation DGR'", R'" that are substantially parallel.

The drive gear **4650** is supported for rotation by a bearing support assembly **4660** (FIGS. **133** and **139**A) that, in one exemplary embodiment, comprises a ball bearing assembly **4662**, like the ball bearing assembly **662**, **2662** of the power operated rotary knives **100**, **2100**. The ball bearing assembly **4662** includes a plurality of balls **4666** trapped between an inner race **4664** and an outer race **4664**. A central opening **4670** (FIG. **133**) of the drive gear **4650** receives the outer race **4664** of the ball bearing assembly **4662**. The ball bearing assembly **4662** is secured to the gearbox housing **4113** by a threaded fastener **4672** that threads into an opening **4140** (FIG. **153**) in a downwardly extending projection **4142** extending from a bottom portion **4141** of an inverted U-shaped forward section **4118** of the gearbox housing **4113**.

Gearbox Housing **4113**

The gearbox housing **4113** (FIGS. **133**, **149** and **153**-**154**), in one exemplary embodiment, includes a cylindrical rearward section **4116** (in the rearward direction RW'" away from the blade housing **4400**), an inverted U-shaped forward section **4118** (in the forward direction FW toward the blade housing **4400**) and a generally rectangular base section **4120** disposed axially below the inverted U-shaped forward section **4118**. The gearbox housing **4113** includes the gearbox cavity or opening **4114** which defines a throughbore **4115** extending through the gearbox housing **4113** from a rearward end **4122** to a forward end **4124** of the gearbox housing **4113**. The throughbore **4115** extends generally along the handle assembly longitudinal axis LA'" and provides a cavity for the pinion gear input shaft **4612**. The throughbore **4115** includes the axially spaced apart recesses **4126**, **4128** which receive the pinion gear ball bearing assemblies **4630**, **4632** to support the pinion gear **4610** for rotation about its axis of rotation PGR'". The inverted U-shaped forward section **4118** and the cylindrical rearward section **4116** combine to define an upper surface **4130** of the gearbox housing **4113**.

The generally rectangular shaped base **4120** of the gearbox housing **4113** extends downwardly from the inverted U-shaped forward section **4118**, i.e., away from the gearbox housing upper surface **4130**. As can be seen in FIGS. **153** and **154**, the rectangular base **4120** includes a front wall **4120***a*, a rear wall **4120***b*, an upper wall **4120***c*, a bottom wall **4120***d*, an outer wall **4120***e*, and an inner wall **4120***f*. The front wall **4120***a*, the upper wall **4120***c*, the bottom wall **4120***d* and the outer wall **4120***e* are generally planar. As is best seen in FIG. **153**, extending radially inwardly into the front wall **4120***a* of the rectangular base **4120** and the bottom portion **4141** of the inverted U-shaped forward section of the gearbox housing **4113** are first and second recesses **4120***g*, **4120***h*. The first arcuate recess **4120***g* is an upper recess, that is, the upper recess **120***g* is adjacent the bottom portion **4141** of the inverted U-shaped forward section **4118**. The second arcuate recess **4120***h* is a lower recess and extends through the bottom wall **120***c* of the rectangular base **120**. The first, upper recess **4120***g* provides clearance for the bevel gear **4652** of the drive gear **4650**, while the second, lower recess **4120***h*, which is wider than the upper recess **4120***g*, provides clearance for the spur gear **4654** of the drive gear **4650**.

The lower portion **4141** of the inverted U-shaped forward section **4118** also includes a port or opening **4136** that provides a passageway between the throughbore **4115** and the first, upper recess **4120***g*. The opening **4136** provides for clearance of an upper portion of the bevel gear **4652** and provides a passageway for communication of cleaning fluid injected into the throughbore **4115** from the proximal end **4122** of the gearbox housing **4113** to enter the regions of the first and second recesses **4120***g*, **4120***h* for purposes of cleaning the drive gear **4650**.

The bottom portion **4141** of the inverted U-shaped forward section **4118** includes the downwardly extending projection **4142**. The downwardly extending projection **4142** includes a cylindrical stem portion **4143** that defines the threaded opening **4140** extending through the downwardly extending projection **4142**. A central axis through the threaded opening **4140** defines and is coincident with the axis of rotation DGR'" of the drive gear **4650**. The threaded opening **4140** receives the fastener **4672** to secure the drive gear ball bearing assembly **4662** to the downwardly extending projection **4142**. Specifically, the inner race **4664** of the drive gear ball bearing assembly **4662** is secured to the cylindrical stem portion **4143**. The upper and lower arcuate recesses **4120***g*, **4120***h* are centered about the drive gear axis of rotation DGR'" and the central axis of the threaded opening **4140**.

As can be seen in FIG. **154**, an inner surface **4145** of the cylindrical rearward section **4116** of the gearbox housing **4113** defines a threaded region **4149**, adjacent the proximal end **4122** of the gearbox housing **4113**. The threaded region **4149** of the gearbox housing **4113** receives a mating threaded portion **4258** of a frame screw **4252** of the hand piece retaining assembly **4250** to secure the hand piece **4200** to the gearbox housing **4113**. An outer surface **4146** of the cylindrical rearward section **4116** of the gearbox housing **4113** defines a plurality of axially extending splines **4148**.

Frame Body **4150**

The frame body **4150** (FIGS. **148**, **150** and **151**) includes the pair of arcuate arms **4160**, **4162** extending outwardly from a central cylindrical region **4154**. The arcuate arms **4160**, **4162** include respective threaded openings **4172** that receive the pair of threaded fasteners **4170**. A front or forward portion of the frame body **4150** defines the arcuate mounting pedestal **4152**. The arcuate mounting pedestal **4152** provides a seating region **4152***a* (FIG. **148**) to receive the mounting section **4402** of the blade housing **4400**. Specifically, the mounting pedestal **4152** includes an inner wall **4174**, an upper wall **4176** extending radially in a forward direction FW" from an upper end of the inner wall **4174**, and a lower wall or ledge **4178** extending radially in a forward direction FW'" from a lower end of the inner wall **4174**. The

The frame body **4150** slides downwardly over an upper surface **4130** of the gearbox housing **4113**. The central cylindrical region **4154** of the frame body **4150** defines the interior socket **4156**. An inner surface **4158** of the frame body **4150** defining the socket **4156** is configured and contoured to snuggly fit over and engage the upper surface **4130** of the gearbox housing **4113**, that is, the frame body socket **4156** is configured such that the inner surface **4158** engages the cylindrical rearward section **4116**, the inverted U-shaped forward section **4118**, and the rectangular base **4120** of the gearbox housing **4113**. When the gearbox housing **4113** is received in the frame body **4150**, the frame body socket **5156** overlies the outer wall **4120***e* of the gearbox housing base **4120** and a recessed portion **4180** (FIGS. **150** and **151**) of a bottom wall **4182** of the frame body **4150** is flush with the bottom wall **4120** (FIG. **153**) of the gearbox housing base **4120**.

A necked down or smaller diameter region **4158***a* (FIG. **151**) of the inner surface **4158** of frame body **4150** snuggly fits over an upper portion **4132** (FIGS. **149** and **154**) of the cylindrical rearward section **4116** of the gearbox housing **4113**. A larger diameter region **4158***b* of the inner surface **4158** of the frame body **4150** snuggly fits over an upper portion **4134** of the inverted U-shaped forward section **4118** of the gearbox housing **4113**. As is best seen in FIG. **139**A, clearance for the gear head **4614** of the pinion gear **4610** is provided by a space or gap between a forward wall **4158***c* (FIG. **150**) defined by the inner surface **158** of the frame body **4150** and a front wall **4138** of the inverted U-shaped forward section **4118** of the gearbox housing **4113**. The front wall **4138** of the inverted U-shaped forward section **41118** defines the distal end **4124** of the gearbox housing **4113**.

When the frame body **4150** is slid onto the gearbox housing **4113**, a pair of parallel horizontal ledges **4186** of the inner surface **4158** of the frame body **4150** rest on the upper wall **4120***c* of the base section **4120** of the gearbox housing **4113** to prevent relative movement of the gearbox housing **4113** with respect to the frame body **4150** in the upward direction UP'''. A stepped shoulder **4147** (FIG. **154**) formed between the cylindrical rearward section **4116** and the inverted U-shaped forward section **4118** abuts a stepped shoulder formed between the small diameter portion **4158***a* and the large diameter portion **4158***b* of the inner surface **4158** of the frame body **4150** to prevent movement of the gearbox housing **4113** with respect to the frame body **4150** in the rearward direction RW'''.

Frame Body Bottom Cover **4190**

After sliding the frame body **4150** over the gearbox housing **4113**, the frame body **4150** is secured in place with respect to the gearbox housing **4113** by the frame body bottom cover **4190** (FIGS. **148** and **152**). The frame body bottom cover **4190** fits a recessed portion **4180** of a bottom surface **4182** of the frame body **4150**. A pair of threaded fasteners **4192** passes through respective openings **4194** in the frame body bottom cover **4190** and thread into an aligned pair of threaded openings **4184** in the recessed portion **4180** of the frame body **4150**. When the fasteners **4192** are threaded into the openings **4184** of the frame body **4150**, an upper surface **4196** of the bottom cover **4190** bears against the bottom wall **4120***d* of the base section **4120** of the gearbox housing **4113** and against the recessed portion **4180** of the bottom surface **4182** of the frame body **4150** to secure the gearbox housing **4113** to the frame body **4150**.

As can best be seen in FIG. **138**, when the frame body bottom cover **4190** is installed, a lower surface **4195** (FIG. **148**) of the bottom cover **4190** is generally flush with the bottom surface **4182** of the frame body **4150**. A recess **4196***a* (FIG. **152**) in the upper surface **4196** of the frame body bottom cover **4190** provides clearance for the fastener **4672** which supports the drive gear ball bearing support assembly **4662** of the gearbox **602**.

Securing Blade-Blade Housing Combination to Gearbox Housing

The frame body **4150** releasably secures the blade-blade housing combination **4550** to the gearbox housing **4113**. When the blade blade housing combination **4550** is assembled and the mounting section **4402** of the blade housing **4400** is properly aligned and moved into engagement with the arcuate mounting pedestal **4152** of the frame body **4150**: 1) the outer wall **4406** of the blade housing mounting section **4402** bears against the inner wall **4174** of the arcuate mounting pedestal **4152** and the forward facing wall **4120***a* (FIG. **153**) of the base section **4120** of the gearbox housing **4113**; 2) the first upper end **4408** of the blade housing mounting section **4402** bears against the upper wall **4176** of the arcuate mounting pedestal **4152**; and 3) a radially inwardly stepped portion **406***a* of the outer wall **406** of the blade housing mounting section **402** bears against an upper face and a forward face of the radially outwardly projecting mounting pedestal lower wall or ledge **4178** (FIGS. **133**, **148** and **151**) of the arcuate mounting pedestal **4152** of the frame body **4150**.

The frame body bottom cover **4190** includes a radially outwardly projecting stepped portion **4197** (FIG. **152**) formed in a front wall **4197***a* of the bottom cover **4190** that continues the lower wall or ledge **4178** of the arcuate mounting pedestal **4152** and also continues a portion of the inner wall **4174** of the arcuate mounting pedestal **4152** of the frame body **4150** across the spaced apart axially recessed portions **4180** on the bottom surface **4182** of frame body **4150**.

The pair of fasteners **4170** of the arcuate arms **4160**, **4162** of the frame body **4150** are threaded into respective threaded openings **4422** of the mounting inserts **4420** of the blade housing mounting section **4402** to secure the blade-blade housing combination **4550** to the frame body **4150** thereby coupling the blade-blade housing combination **4550** to the gearbox housing **4113**.

A forward wall **4154***a* (FIGS. **133**, **148** and **151**) of the central cylindrical region **4154** of frame body **4150** includes a projection **4198** that supports a steeling assembly **4199**. The steeling assembly, shown schematically in FIGS. **130** and **131**, of the power operated rotary knife **4100** is similar in structure and function to the steeling assembly **199** of the power operated rotary knife **100**.

Handle Assembly **4110**

As is best seen in FIG. **131**, the handle assembly **4110** of the power operated rotary knife **4100** includes the hand piece **4200** and the hand piece retaining assembly **4250**. The handle assembly **4110** extends along a longitudinal axis LA'''. As best seen in FIGS. **131** and **139**, the hand piece **4200** of the handle assembly **4110** includes an outer gripping surface **4202** and an inner surface **4204**. The inner surface **4204** defines a throughbore **4206** that extends along the longitudinal axis LA''' between a front wall **4214** and the enlarged proximal end **4210** of the hand piece **4200**. The inner surface **4204** of the hand piece **4200** defines a plurality of splines **4212** adjacent the front wall **4214** and a stepped shoulder **4408** rearward or proximal to the plurality of splines **4212**.

As can be seen in FIG. **131**, the enlarged proximal end **4210** of the hand piece **4200** includes the drive shaft latching assembly **4275**, similar in structure to the drive shaft latching assembly **4275** of the power operated rotary knife **3200**, for releasably securing a flexible shaft drive assembly (similar to the shaft drive assembly **700** of the power operated rotary knife **100**) to the handle assembly **4110**.

The hand piece retaining assembly **4250** of the power operated rotary knife **4100** is similar to the hand piece retaining assembly **3250** of the power operated rotary knife **3100**. Specifically, the hand piece retaining assembly **4250** of the handle assembly **4100** includes the frame screw **4252** and a coil spring **4270** extending in a rearward direction RW" from the frame screw **4252**. The frame screw **4252** includes the threaded outer surface **4258** at a distal end **4256** of the frame screw **4252**. As is best seen in FIG. **139**, the threaded outer surface **4258** of the frame screw **4252** threads into the threaded region **4149** defined on the inner surface **4145** of the cylindrical rearward section of the cylindrical rearward section **4116** of the gearbox housing **4113** to releasably secure the hand piece **4200** to the gearbox housing **4113**.

When the frame screw **4252** is threaded into the threaded interior region **4149** of the gearbox housing **4113**, an outwardly extending central collar **4254** of the frame screw **4252** bears against the stepped shoulder **4208** of the inner surface **4204** of hand piece **4200** to prevent the hand piece **4200** from moving in the rearward direction RW'". At the same time, the front wall **4214** of the hand piece **4200** bears against a shoulder **4144** (FIG. **154**) of the cylindrical rearward section **4116** of the gearbox housing **4113** and against the rearward wall **4159** (FIG. **150**) of the frame body **4150** to prevent the hand piece **4200** from moving in the forward direction FW'".

The plurality of splines **4148** of the gearbox housing **4113** accept and interfit with the plurality of splines **4212** formed on the inner surface **4204** of the hand piece **4200**. The coacting plurality of splines **4148** of the gearbox housing **4113** and the plurality of splines **4212** of the hand piece **4200** allow the hand piece **4200** to be oriented at any desired rotational position about the handle assembly longitudinal axis LA'" with respect to the gearbox housing **4113**.

Fifth Exemplary Embodiment—Power Operated Rotary Knife **5100**

Overview

A fifth exemplary embodiment of a power operated rotary knife of the present disclosure is shown generally at **5100** in FIGS. **155** and **156**. The power operated rotary knife **5100** includes a handle assembly **5110**, a detachable head assembly **5111**, and a drive mechanism **5600**. The head assembly **5111**, best seen in FIGS. **157-165**, of the power operated rotary knife **5100** includes a gearbox assembly **5112**, a rotary knife blade **5300**, a blade housing **5400**, and a blade-blade housing support or bearing structure **5500**. The power operated rotary knife **5100** is similar in configuration and function to the power operated rotary knife **2100** of the second embodiment and, like the power operated rotary knife **2110**, is particularly suited for use with small diameter rotary knife blades.

The rotary knife blade **5300** is supported for rotation with respect to the blade housing **5400** by the blade-blade housing bearing structure **5500**, which is similar to the blade-blade housing bearing structures **2500** of the power operated rotary knife **2100**. The blade-blade housing bearing structure **5500**, includes, in one exemplary embodiment, an elongated rolling bearing strip (FIGS. **174** and **175**) disposed in an annular passageway **5504** (FIG. **175**) formed between opposing bearing surfaces **5319**, **5459** of the rotary knife blade **5300** and the blade housing **5400**, respectfully. The elongated rolling bearing strip **5502**, like the elongated rolling bearing strip **2502** of the power operated rotary knife **2100**, includes a plurality of rolling bearings **5506** rotatably supported in space apart relationship in a flexible separator cage **5508** disposed in a flexible separator cage **5508**.

An assembled combination of the rotary knife blade **2300**, the blade housing **2400**, and the blade-blade housing bearing structure **2500** will be referred to as the blade-blade housing combination **5550** (FIGS. **166-173**). The blade-blade housing bearing structure **5500** both releasably secures the rotary knife blade **5300** to the blade housing **5400** and provides a bearing structure to support the rotary knife blade **5300** for rotation about an axis of rotation R"" (FIGS. **155** and **164**).

The gearbox assembly **5112** includes a gearbox housing **5113** and a gearbox **5602** defining a gear train **5604**. Similar to the gear train **2604** of the power operated rotary knife **2100**, the gear train **5604** of the power operated rotary knife **5100** includes a pinion gear **5610** and a drive gear **5650**. The pinion gear **5610** is rotatably driven about a pinion gear axis of rotation PGR"" (FIG. **164**) by a flexible shaft drive assembly (not shown). The flexible shaft drive assembly (not shown) is similar to the flexible shaft drive assembly **700** of the power operated rotary knife **100**.

A gear head **5614** of the pinion gear **5610**, in turn, rotatably drives a drive gear **5650** about a drive gear axis of rotation DGR' (FIG. **164**). As was the case with the gear train **2604** of the power operated rotary knife **2100**, the drive gear **5650** is a double gear that includes a first upper bevel gear **5652** which meshes with a set of bevel gear teeth **5616** of the gear head **5614** of the pinion gear **5610** to rotate the drive gear **5650**, while a second lower spur gear **5654** of the drive gear **5650** engages a drive gear **5328** of the rotary knife blade **5300** forming an involute gear drive **5658** (FIG. **164**) to rotate the knife blade **5300** about its axis of rotation R'. The upper bevel gear **5632** and the lower spur gear **5654** of the drive gear **5650** are concentric with the drive gear rotational axis DGR" and are spaced axially apart with respect to the rotational axis DGR".

Other components of the drive mechanism **5600** of the power operated rotary knife **2100** include components external to the head and handle assemblies **5111**, **5110** of the power operated rotary knife **5100**. These external components include a drive motor (not shown) and the flexible shaft drive assembly (not shown) which rotates the pinion gear **5610**. Such components of the power operated rotary knife **5100** are similar to the corresponding components discussed with respect to the power operated rotary knife **100**, e.g., the flexible shaft drive assembly **700** and the drive motor **800**.

As is best seen in FIG. **156**, the handle assembly **5110** of the power operated rotary knife **5100** includes a hand piece **5200** and a hand piece retaining assembly **5250**, similar to the hand piece **2200** and the hand piece retaining assembly **2250** of the power operated rotary knife **2100**. The handle assembly **5110** extends along a longitudinal axis LA"" (FIGS. **155** and **164**), which is substantially orthogonal to and intersects the rotary knife blade axis of rotation R'. The hand piece retaining assembly **5250** includes an elongated central core **2252** and a handle spacer ring **5290**. The elongated central core **5252** includes an outer surface **5256** that includes a threaded portion **5262** at a distal end **5264** of the core **5252**. The threaded portion **5262** of the elongated core **5252** threads into threads **5149** (FIG. **204**) formed on an inner surface **5145** of a cylindrical rearward section **5116** of the gearbox housing **5113** to secure the hand piece **5200** to the gearbox housing **5113**.

The elongated core **5252** of the hand piece retaining assembly **5250** includes a drive shaft latching mechanism **5275** (FIGS. **155** and **156**), like the drive shaft latching mechanisms **275**, **2275** of the power operated rotary knives **100**, **2100**. The drive shaft latching mechanism **5275** includes a slidable latch **5276** which functions to secure the shaft drive assembly to the handle assembly **5110** of the power operated rotary knife **5100**.

One of the primary differences between the power operated rotary knife **5100** and the power operated rotary knife **2100**, discussed previously, involves the relative positions or locations of the bearing race and the set of spur gear teeth of the respective rotary knife blades **2300**, **5300**. Specifically, as can best be seen in FIG. **71**, in the rotary knife blade **2300** of the power operated rotary knife **2100**, the bearing surface **2319** is located axially above the driven gear **2328**, that is, the bearing surface **2319** is located closer to the upper end **2306** of the blade body **2302** than the driven gear **2328**. By contrast, as can best be seen in FIG. **175**, in the rotary knife blade **5300** of the power operated rotary knife **5300**, the bearing surface **5319** is located axially below a driven gear **5328** of the knife blade **5300**, that is, the driven gear **5328** is closer to an upper end **5306** of a body **5302** of the knife blade **5300** than the bearing surface **5319**. Note, however, that the driven gear **5328** is still axially spaced from the upper end **5306** of the knife blade body **5302**.

In the power operated rotary knife **5100**, the driven gear **5328** of the rotary knife blade **5300** is positioned closer to the upper end **5306** of the blade body **5302** than was the case with the driven gear **2328** of the rotary knife blade **2300** of the power rotary knife **2100**. This results in a number of modifications of the gearbox assembly **5112** including the configuration of the gearbox housing **5113**, a frame body **5150** and a frame body bottom cover **5190**. The position of the blade housing **5400** relative to the gearbox housing **5113** is lower (that is, in a downward direction DW"" in FIG. **161**) compared to the relative position of the blade housing **2400** and the gearbox housing **2113** in the power operated rotary knife **2100**. The lower position of the blade housing **5400** relative to the gearbox housing **5113** provides for proper meshing of the driven gear **5328** of the rotary knife blade **5300** and the lower spur gear **5654** of a drive gear **5650** (as can be seen in the schematic sectional view of FIG. **164**).

To minimize the amount that the blade housing **5400** of the power operated rotary knife **5100** must be lowered with respect to the gearbox housing **5113** and still have proper alignment of the driven gear **5328** of the rotary knife blade **5300** and the lower spur gear **5654** of the drive gear **5650**, the pinion gear **5610** and the drive gear **5650** of the drive train **5604** of the power operated rotary knife **5100** are positioned slightly higher (that is, in an upward position UP"" in FIG. **161**) in the gearbox housing **5113** than was the case with the pinion gear **2610** and drive gear **2650** of the drive train **2604** of the power operated rotary knife **2100**. That is, a throughbore **5115** of the gearbox housing **5113**, which receives the pinion gear **5610**, is raised slightly upwardly within the gearbox housing **5113**, as compared to the throughbore **2115** of the gearbox housing **2113** of the power operated rotary knife **2100**.

In the power operated rotary knife **5100**, raising the pinion gear **5610** and the drive gear **5650** with respect to the gearbox housing **5113** is accomplished by modifying the larger sleeve bushing **5632** of the pinion gear bearing support assembly **5630**, as compared to the larger sleeve bushing **2632** of the pinion gear bearing support assembly **5630** of the power operated rotary knife **2100**. The larger sleeve bushing **5632** includes a cylindrical body **5637** and an annular forward head **5636**. A central opening **5634** of the sleeve bushing **5632** receives an input shaft **5612** of the pinion gear **5610**. The annular forward head **5636** includes a flat **5638** to prevent rotation of sleeve bushing **5632** with rotation of the pinion gear **5610**.

In a modification to the configuration to the corresponding sleeve bushing **2632** of the power operated rotary knife **2100**, in the sleeve bushing **5632** of the power operated rotary knife **5100**, a longitudinal recess **5639** is formed in an upper surface **5639***a* of the cylindrical body **5637**. As can best be seen in FIG. **212**, the longitudinal recess **5639** essentially continues an upper surface of the flat **5638** of the annular forward head **5636**. This allows the throughbore **5114** and the sleeve bushing **5632** to both be positioned slightly higher in the gearbox housing **5113** than would otherwise be the case without the longitudinal recess **5639**. Since the position of the throughbore **5115** and the sleeve bushing **5632** within the gearbox housing **5113** determine the position of the pinion gear **5610**, the pinion gear **5610** is positioned higher within the gearbox housing **5113**, as compared to the relative positions of the pinion gear **2610** and gearbox housing **2113** in the power operated rotary knife **2100**.

As the pinion gear **5610** and drive gear **5650** are substantially identical to the pinion gear **2610** and drive gear **2650** of the power operated rotary knife **2100**, the higher position of the pinion gear **5610** within the gearbox housing **5113** also allows the position of the drive gear **5650** to be correspondingly raised with respect to the gearbox housing **5113**. Recall that the upper bevel gear **5652** of the drive gear **5650** meshes with the gear head **5614** of the pinion gear **5610**. Raising the position of the drive gear **5650** with respect to the gearbox housing **5113** and lowering the position of the blade housing **5400** with respect to the gearbox housing **51113** allows for the lower spur gear **5654** of the drive gear **5650** to properly mesh with the driven gear **5328** of the rotary knife blade **5300**, as can be seen in FIG. **164**.

The head assembly **5111** of the power operated rotary knife **5100** is similar to the head assembly **2111** of the power operated rotary knife **2100** in that both have a smaller physical “footprint” than, for example, the head assembly **111** of the power operated rotary knife **100**. However, it should be recognized that, if desired, the power operated rotary knife **5100** may effectively be used with large diameter rotary knife blades just as the power operated rotary knife **100** could, if desired, be effectively used with small diameter rotary knife blades.

For brevity, components and assemblies of the power operated rotary knife **5100** that are substantially similar to corresponding components and assemblies of the power operated rotary knife **2100** and/or the power operated rotary knife **100**, such as the handle assembly **5110**, the blade-blade housing structure **5500**, the drive mechanism **5600**, the gear train **5604**, the flexible shaft drive assembly, and the drive motor, among others, will not be described in detail below. It being understood by one of ordinary skill in the art that the discussion of the structure and function of the components and assemblies of the power operated rotary knives **100**, **2100**, **3100**, **4100**, set forth above, is applicable to and is incorporated into the discussion of the power operated rotary knife **5100**, set forth below.

Rotary Knife Blade **5300**

In one exemplary embodiment and as best seen in FIGS. **176-179**, the rotary knife blade **5300** of the power operated rotary knife **5100** is a one-piece, continuous annular structure that is supported for rotation about the axis of rotation R"". The rotary knife blade **5300** includes the body section **5302** and a blade section **5304** extending axially from the body **5302**. The body **5302** of the rotary knife blade **5300** includes the upper end **5306** and a lower end **5308** spaced axially apart from the upper end **5306**. The knife blade body **5302** further includes an inner wall **5310** and an outer wall **5312** spaced radially apart from the inner wall **5310**. The blade section **5304** of the rotary knife blade **5300** includes a blade edge **5350** defined at a distal end portion **5352** of the blade section **5304**. The blade section **5304** further includes an inner wall **5354** and an axially spaced apart outer wall **5356**. A short angled portion **5358** bridges the inner and outer walls **5354**, **5356**. As can best be seen in FIG. **179**, the blade edge **5350** is formed at the intersection of the short angled portion **5358** and the blade section inner wall **5354**. The rotary knife blade **5300** defines an inner wall **5360** which is formed by the inner wall **5310** of the body **5302** and the inner wall **5354** of the blade section **5304**. In one exemplary embodiment, the rotary knife blade **5300** includes a knee or discontinuity **5360***a* in the body region of the inner wall **5360**, although it should be appreciated that, depending on the specific configuration of the rotary knife blade **5300**, the blade may be formed such that there is no discontinuity in the inner wall **5360**.

The rotary knife blade **5300** is a "straight blade" style rotary knife blade. Although, it should be recognized that other rotary knife blade styles may be used in the power operated rotary knife **5100**. A radially inwardly step **5314** (FIG. **179**) of the body outer wall **5312** defines a line of demarcation between a radially narrower, upper gear and bearing region **5316** of the blade body **5302** and a radially wider, lower support region **5318** of the body **5302**. As can be seen in FIG. **179**, the upper gear and bearing region **5316** is narrow in cross section being recessed inwardly from an outermost radial extent **5318***a* of the lower support region **5318** defined by the blade body outer wall **5312**. The upper gear and bearing region **5316**, in one exemplary embodiment, is generally rectangular in cross section and includes a radially thin upper section **5316***a*, a generally vertical or axially extending middle section **5316***b*, and a generally vertically extending lower section **5316***c*. As can be seen, the middle section **5316***b* of the upper gear and bearing region **5316** is radially recessed with respect to the outermost radial extent **5318***a* of the outer wall **5312**. The lower section **5316***e* and the upper section **5316***a* of the upper gear and bearing region **5316** are both radially recessed with respect to the middle section **5316***b*.

The rotary knife blade **5300** includes the bearing surface **5319**. In one exemplary embodiment of the power operated rotary knife **5100** and as best seen in FIGS. **175** and **179**, the rotary knife blade bearing surface **5319** comprises a bearing race **5320**, which is defined by and extends radially inwardly into the outer wall **5312** in the lower section **5316***b* of the upper gear and bearing region **5316**. In one exemplary embodiment, the knife bearing race **5320** defines a generally arcuate bearing face **5322** in a central portion **5324** of the bearing race **5320**. As can be seen the lower section **5316***c* of the upper gear and bearing region **5316** includes vertical portions **5326***a*, **5326***b* respectively extending axially above and below the bearing race **5320**.

The body outer wall **5312** in the middle section **5316***b* of the upper gear and bearing region **5316** of rotary blade body **5302** defines the driven gear **5328** comprising a set of gear teeth **5330** formed so as to extend radially outwardly in a stepped portion **5331** of the outer wall. The driven gear **5328** is axially above the bearing race **5320**, that is, closer to the first upper end **5306** of the blade body **5302**. The driven gear **5328**, in one exemplary embodiment, defines a plurality of vertically or axially oriented spur gear teeth **5332**.

Advantageously, as can be seen in FIG. **179**, both the set of gear teeth **5330** of the rotary knife blade driven gear **5328** and the knife blade bearing race **5320** are axially spaced from the upper end **5306** of the rotary knife blade body **5302** by the recessed upper section **5316***a* of the upper gear and bearing region **5316**. The driven gear **5328** is also axially spaced from arcuate bearing race **5320** of the body **5302** by a vertical portion **5317** of the middle section **5316***b* of the upper gear and bearing region **5316** and the upper vertical portion **5326***a* of the lower section **5316***c* above bearing race **5320** of the upper gear and bearing region **5316**. The knife blade bearing race **5320** is also advantageously axially spaced from the lower end **5308** of the blade body **5302** by the lower support portion **5318** of the knife blade body **5302** and the lower vertical portion **5326***b* of the lower section **5316***c* below the bearing race **5320**.

The set of gear teeth **5330** of the driven gear **5328** of the rotary knife blade **5300** is axially spaced from the upper end **5306** of the knife blade body **5302**. This advantageously protects the set of gear teeth **5330** from damage that they would otherwise be exposed to if, as is the case with conventional rotary knife blades, the set of gear teeth **5330** were positioned at the upper end **5306** of the blade body **5302** of the rotary knife blade **5300**. Additionally, spacing the set of gear teeth **5330** from both axial ends **5306**, **5308** of the knife blade body **5302**, impedes or mitigates the migration of debris generated during the cutting process into the region of the knife blade driven gear **5328**. Debris in the region of knife blade driven gear **5328** may cause or contribute to a number of problems including blade vibration, premature wear of the driven gear **5328** or the mating drive gear **5650** of the gear train **5604**, and "cooking" of the debris.

Similar advantages exist with respect to axially spacing the blade bearing race **5320** from the upper and lower ends **5306**, **5308** of the blade body **5302**. As will be explained below, the rotary knife blade body **5302** and the blade housing **5400** are configured to provide radially extending projections or caps which provide a type of labyrinth seal to impede ingress of debris into the regions of the knife blade driven gear **5328** and the blade-blade housing bearing structure **5500**. These labyrinth seal structures are facilitated by the axial spacing of the knife blade drive gear **5328** and the blade bearing race **5320** from the upper and lower ends **5306**, **5308** of the blade body **5302** of the rotary knife blade **5300**.

As can best be seen in FIG. **164**, a lower spur gear **5654** of the drive gear **5650** of the gear train **5604** meshes with the spur gear teeth **5332** of the knife blade driven gear **5328** to rotate the rotary knife blade **5300** with respect to the blade axis of rotation R"". This gearing combination defines an involute spur gear drive, as was previously described with respect to the gear train **2604** of the drive mechanism **2600** of the power operated rotary knife **2100**.

As can be best seen in FIG. **179**, in order to impede ingress of fragments or pieces of meat, bone, and/or gristle generated during cutting/trimming operations, and/or other debris into the driven gear **5328** and the bearing race **5320** of the rotary knife blade **5300**, the outer wall **5312** in the lower support portion of blade body **5318** includes a radially outwardly extending projection or cap **5318***b*. The outwardly extending cap **5318***b* includes the outermost radial extent **5818***a* of the lower support portion **5318** of the rotary knife blade body **5302**. As can best be seen in FIG. **179**, the cap **5318***b* is axially aligned with and, when viewed in an upward direction UP' from the lower end **5308** of the knife blade body **5302**, overlies at least a portion of the set of gear teeth **5330**. A radial outer surface **5330***a* of the set of gear teeth **5330**, when viewed in three dimensions, defines a first imaginary cylinder **5346** (shown schematically in dashed line in FIG. **179**). A radial inner surface **5330***b* of the set of gear teeth **5330**, when viewed in three dimensions, defines a second, smaller diameter imaginary cylinder **5347** (also shown schematically in dashed line in FIG. **179**).

Viewed in an upward direction UP"" from the lower end **5308** of the knife blade body **5302**, the cap **5318***b* is aligned with and overlies at least a portion of an annulus **5349** defined between the first imaginary cylinder **5346** and the second, smaller diameter cylinder **5347**. As the annulus **5349** is coincident with a volume occupied by the set of gear teeth **5330**, the cap **5318***b* is aligned with and overlies at least a portion of the set of gear teeth **5330**. Further, the cap **5318***b* extends radially outwardly beyond the imaginary cylinder **5346** defined by the radial outer surface **5330***a* of the set of gear teeth **5330**.

As can best be seen schematically in FIG. **175**, the outwardly extending cap **5318***b* is axially aligned with and overlies at least a portion of a bottom wall or end **5458** of a blade support section **5450** of the blade housing **5400** to form a type of labyrinth seal and minimize ingress of debris into the regions of the driven gear **5328** and the annular passageway **5504** defined between the knife blade bearing surface **5319** and the blade housing bearing surface **5459**. The overlapping cap **5318***a* of the rotary knife blade body **5302** and the bottom wall **5458** of the blade support section **5450** of the blade housing **5400** inhibit ingress of debris from entering between the outer wall **5312** of the blade body **5302** of the rotary knife blade **5300** and the blade housing **5400** and working into the region of the knife blade driven gear **5328** and the annular passageway **5504**. As best seen schematically in FIG. **175**, for clearance purposes, there is a small axial gap between an upper surface **5318***c* of the cap **5318***b* and the bottom wall **5458** of the blade housing blade support section **5450**. The upper surface **5318***c* of the cap **5318***c* is a portion of the radially inward step **5314** defining the line of demarcation between upper gear and bearing portion **5316** of the blade body **5302** and the lower support portion **5318** of the blade body **5302**. An upper portion of the knife blade inner wall **5360** defines a cutting opening CO"" (FIGS. **157**, **159** and **160**) of the power operated rotary knife **5100**,

Blade Housing **5400**

In one exemplary embodiment and as best seen in FIGS. **181-185**, the blade housing **5400** of the power operated rotary knife **5100** comprises one-piece, continuous annular structure that includes the mounting section **5402** and the blade support section **5450**. In one exemplary embodiment, the blade housing **5400** is continuous about its perimeter. The blade-blade housing bearing structure **5500** secures the rotary knife blade **5300** to the blade housing **5400**. Accordingly, removal of the knife blade **5300** from the blade housing **5400** is accomplished by removing the elongated rolling bearing strip **5502** of the blade-blade housing bearing structure **5500** from the power operated rotary knife **5100**. The blade-blade housing bearing structure **5500** permits use of the continuous blade housing **5400** because there is no need to expand the blade housing diameter to remove the knife blade **5300** from the blade housing **5400**.

The mounting section **5402** of the blade housing **5400** extends radially outwardly from the blade support section **5450** and subtends an angle of approximately 120° or, stated another way, extends approximately ⅓ of the way around the circumference of the blade housing **5400**. The mounting section **5402** is both axially thicker and radially wider than the blade support section **5450**.

The blade housing mounting section **2402** includes an inner wall **5404** and a radially spaced apart outer wall **5406** and a first upper end **5408** and an axially spaced apart second lower end **5410**. At forward ends **5412**, **5414** of the mounting section **5402**, there are tapered regions **5416**, **5418** (FIG. **181**) that transition between the upper end **5408**, lower end **5410** and outer wall **5406** of the mounting section **5402** and the corresponding upper end **5456**, lower end **5458** and outer wall **5454** of the blade support section **5450**. The mounting section **5402** defines an opening **5420** (FIGS. **180** and **183**) that extends radially between the inner and outer walls **5404**, **5406**. The radially extending opening **5420** is bounded by and extends between upright supports or pedestals **5422** and an upper surface **5428***a* of a base **5428** that bridges the pedestals **5422**. The pedestals **5422** extend axially upwardly from an upper surface **5428***a* of the base **5428**.

As can best be seen in FIGS. **180** and **181**, the base **5428** and the pedestals **5422** above the base **5428** together define two axially extending apertures **5430** between the upper and lower ends **5408**, **5410** of the mounting section **5402**. The base apertures **5430** receive a pair of threaded fasteners or screws **5434**. The threaded fasteners **5434** pass through the base apertures **5430** and thread into respective threaded openings **5130** of a horizontal planar seating surface **5133** of an L-shaped mounting pedestal **5132** (FIGS. **158** and **203**) defined by a forward mounting portion **5120** of the gearbox housing **5113** to releasably secure the blade-blade housing combination **5550** to the gearbox housing **5113** of the head assembly **5111**. When blade-blade housing combination **5550** is secured to the gearbox housing **5113** using the threaded fasteners, the upper end **5408** of the mounting section **5402** of the blade housing **5400** is seated on the horizontal planar seating surface **5133** of the L-shaped mounting pedestal **5132** of the forward mounting portion **5120** of the gearbox housing **5113**. The outer wall **5406** of the mounting section **5402** of the blade housing **5400** is seated on a vertical planar seating surface **5134** of the L-shaped mounting pedestal **5132** of the forward mounting portion **5120** of the gearbox housing **5113**.

The radially extending opening **5420** of the blade housing mounting section **5402** includes a narrower upper portion **5420***a* and a wider lower portion **5420***b*. A relative width of the opening **5420** is defined by rearward facing surfaces **5438** of the pedestals **5422** that comprise a portion of the outer wall **5406** of the blade housing mounting portion **5402**. The opening **5420** is sized to receive a removable blade housing plug **5440** (FIGS. **186-189**). The blade housing plug **5440** is removably received in the mounting section opening **5420**. When the blade housing plug **5440** is removed from the opening **5420**, access is provided to the elongated rolling bearing strip **5502** of the blade-blade housing bearing structure **5500**.

The blade housing plug **5440** is positioned in the opening **5420** and releasably attached to the blade housing **5400** via a pair of set screws **5446** (FIG. **165**) that, when tightened bear against the upper surface **5428***a* of the mounting section base **5428**. Stepped shoulders **5441** formed in opposite sides **5440***e*, **5440***f* of blade housing plug **5440** bear against mating stepped shoulders **5424** of the pair of pedestals **5422** to secure the blade housing plug **5440** with respect to the blade housing mounting section opening **5420**. When installed in the blade housing mounting section opening **5420**, the blade housing plug **5440** inhibits debris generated during cutting/trimming operations (e.g., pieces or fragments of fat, gristle, bone, etc.) and other foreign materials from migrating to and accumulating on or adjacent the elongated rolling bearing strip **5502** of the blade-blade housing bearing structure **5500** or the driven gear **5328** of the rotary knife blade **5300**.

As can best be seen in FIG. **185**, the blade support section **5450** includes an inner wall **5452** and radially spaced apart outer wall **5454** and a first upper end **5456** and an axially spaced second lower end **5458**. The blade support section **5450** extends about the entire 360° circumference of the blade housing **5400**. The blade support section **5450** in a region of the mounting section **5402** is continuous with and forms a portion of the inner wall **5404** of the mounting section **5402**. The blade support section inner wall **5452** defines a bearing surface **5459**. In one exemplary embodiment of the power operated rotary knife **5100** and as best seen in FIG. **185**, the bearing surface **5459** of the blade housing **5400** comprises a bearing race **5460** that extends radially inwardly into the inner wall **5452**. In one exemplary embodiment, a central portion **5462** of the blade housing bearing race **5460** defines a generally arcuate bearing face **5464**.

As can best be seen in FIGS. **175** and **185**, the blade support section upper end **5456** defines a radially inwardly extending projection or cap **5456***a* that axially overlies at least portions the driven gear **5328** and the bearing race **5320** of the rotary knife blade **5300**. The overlap of the projection or cap **5456***a* of the blade housing **5400** and the driven gear **5328** and bearing race **5320** of the rotary knife blade **5300** protects the blade-blade housing bearing structure **2550**, the bearing races **5320**, **5460** of the knife blade **5300** and the blade housing **5400**, respectively, and the driven gear **5328** of the knife blade **5300**.

Specifically, the overlap of the cap **2456***a* of the blade housing **2400** and an inwardly stepped portion **2348** of the rotary knife blade body **2402** that extends between the recessed upper section **5316***a* of gear and bearing portion **5316** and the upper surface **5330***c* of the set of gear teeth **5330** of the driven gear **5328** forms a type of labyrinth seal. The labyrinth seal inhibits the entry of debris resulting from cutting and trimming operations and other foreign materials into the annular passageway **5504** between facing bearing surfaces **5319**, **5459** of rotary knife blade **5300** and the blade housing **5400** and through which the rolling bearing strip **5502** of the blade-blade housing bearing structure **5500** traverses. As best seen schematically in FIG. **175**, for clearance purposes, there is a small radial gap between a terminal end **5456***b* of the bearing region cap **5456***a* of the blade housing **5400** and the recessed upper section **5316***a* of the gear and bearing portion **5316** the rotary knife blade body **5302**.

As can best be seen in FIG. **185**, advantageously the blade housing bearing race **5460** is axially spaced from both the upper and lower ends **5456**, **5458** of the blade support section **5450**. Specifically, there is a portion **5466** of the inner wall **5452** of the blade support section **5450** extending axially between the blade housing bearing race **5460** and the cap **5456***a* and there an axially extending portion **5468** of the inner wall **5452** extending axially between the bearing race **5460** and the blade support section lower end **5458**.

As is best seen in FIG. **184**, both the right and left tapered regions **5416**, **5418** of the blade housing mounting section **5402** include a cleaning port **5480** for injecting cleaning fluid for cleaning the blade housing **5400** and the knife blade **5300** during a cleaning process. Each of the cleaning ports **5480** includes an entry opening **5481** in the outer wall **5406** of the mounting section **5402** and extends through to exit opening **5482** in the inner wall **5404** of the mounting section **5402**. Lower portions of the respective exit openings **5482** in the mounting section inner wall are in fluid communication with and open into a region of the bearing race **5460** of the blade housing **5400**. The cleaning port **5480** provides for injection of cleaning fluid into bearing race regions **5320**, **5460** of the knife blade **5300** and blade housing **5400**, respectively, and the driven gear **5328** of the knife blade **5300**.

Blade Housing Plug **5440**

As can best be seen in FIGS. **174** and **186-189**, the blade housing plug **5440** includes an upper end **5440***a*, an axially spaced apart a lower end **5440***b*, an inner wall **5440***c* and a radially spaced apart outer wall **5440***d*. The blade housing plug **5440** also includes the pair of stepped shoulders **5441** formed in opposite sides **5440***e* of the blade housing plug **5440**. The inner wall **5440***c* defines an arcuate bearing race **5442** (FIGS. **186** and **189**) that continues the bearing race **5460** of the blade housing blade section inner wall **5452**. When the blade housing plug **5440** is installed in the blade housing plug opening **5420** of the blade housing mounting section **5402**, the radially inner wall **5440***c* of the blade housing plug **5440** defines a portion of the blade housing bearing race **5460** such that the blade housing bearing race **5460** is continuous about substantially the entire 360° circumference of the blade support section **5450**.

As can best be seen in FIG. **187**, the blade housing plug **5440** includes an generally rectangular opening **5445** that extends through the blade housing plug **5440** from outer wall **5440***d* to the inner wall **5440***c*. The upper end **5440***a* of the blade housing plug **5440** also defines a first axially extending arcuate recess **5443** (FIG. **186**). When the blade housing plug **2440** is installed in the blade housing plug opening **5420**, the opening **5445** of the blade housing plug **5440** receives the lower spur gear **5654** of the drive gear **5650** of the drive train **5604** such that the spur gear **5654** meshes with and rotatably drives the driven gear **5328** of the rotary knife blade **5300** and the arcuate recess **5443** of the blade housing plug **5440** provides clearance for the upper bevel gear **5652** of the drive gear **5650**.

A portion of the upper end **5440***a* of the blade housing plug **5440** includes a radially inwardly extending bearing region cap **5444** (FIG. **189**) that continues the radially inwardly extending bearing region cap **5456***a* of the blade support section **5450** of the blade housing **5400**. The upper end **5440***a* of the blade housing plug **5440**, when installed in the blade housing opening **5420**, is flush with and functions as portion of the upper end **5408** of the mounting section **5402** of the blade housing **5400** for purposes of mounting the blade housing **5400** to the horizontal planar seating surface **5133** of the L-shaped mounting pedestal **5132** of the forward mounting portion **5120** of the gearbox housing **5113**. Similarly, the outer wall **5440***d* of the blade housing plug **5440**, when installed in the blade housing opening **5420**, is flush with and functions as a portion of the outer wall **5406** of the mounting section **5402** of the blade housing **5400** for purposes of mounting the blade housing **5400** to the vertical planar seating surface **5134** of the L-shaped mounting pedestal **5132** of the forward mounting portion **5120** of the gearbox housing **5113**.

Blade-Blade Housing Bearing Structure **5500**

The power operated rotary knife **5100** includes the blade-blade housing bearing structure **5500** (best seen in FIGS. **156**, and **174**) that: a) secures the knife blade **5300** to the blade housing **5400**; b) supports the knife blade **5300** for rotation with respect to the blade housing **5400** about the rotational axis R""; and c) defines the rotational plane RP"" (FIG. **164**) of the knife blade **5300**. The blade-blade housing bearing structure **5500** is similar in structure and function to the blade-blade housing bearing structure **2500** of the power operated rotary knife **2100** and reference is made to the prior discussion.

Gearbox **5603** and Gear Train **5604**

The drive mechanism **5600**, a portion of which is schematically shown in FIG. **156**, includes the gearbox assembly **5112** for providing motive power for rotating the rotary knife blade **5300** about its axis of rotation R"". The gearbox assembly **5112** includes the gear train **5604** and two bearing support assemblies, namely, the bearing support assembly **5630** that supports the pinion gear **5610** for rotation about the pinion gear rotational axis PGR", and a bearing support assembly **5660** that supports the drive gear **5650** for rotation about the drive gear rotational axis DGR"". The gear train **5604** of the power operated rotary knife **5100** includes the pinion gear **5610** and the drive gear **5650**. The drive gear **5650** includes the lower spur gear **5654** and an upper bevel gear **5652** which are axially spaced apart and aligned concentrically about the drive gear rotational axis DGR''''. The gear head **5614** of the pinion gear **5610** meshes with the upper bevel gear **5652** of the drive gear **5650** to rotatably drive the drive gear **5650**. The pinion gear **5610**, in turn, is driven by the flexible shaft drive assembly (not shown) and rotates about the axis of rotation PGR'''' (FIG. **164**) of the pinion gear **5610**. The pinion gear **5610** includes the input shaft **5612** extending rearward of the gear head **5614**. The input shaft **5612** extends from a proximal end **5629** (FIG. **156**) to a distal end **5628** adjacent the gear head **5614**. The pinion gear input shaft **5612** includes a central opening **5618** (FIG. **163**). An interior surface **5620** of the input shaft **5612** defines a cross shaped female socket or fitting **5622** that receives a mating male drive fitting of the flexible shaft drive assembly (not shown) which provides for rotation of the pinion gear **5610**.

The pinion gear axis of rotation PGR'''' is substantially parallel to and coextensive or aligned with the handle assembly longitudinal axis LK''''. At the same time, the drive gear **5650** rotates about the drive gear axis of rotation DGR'''' (FIG. **164**) which is substantially parallel to the rotary knife blade axis of rotation R'''' and is substantially orthogonal to and intersects the pinion gear axis or rotation PGR'''' and the handle assembly longitudinal axis LA''''.

The pinion gear bearing support assembly **5630**, in one exemplary embodiment, includes the larger sleeve bushing **5632** and a smaller sleeve bushing **5640**. As can best be seen in FIGS. **156**, **164** and **212-214**, the larger sleeve bushing **2632**, like the sleeve bushing **2632** of the power operated rotary knife **2100**, includes the annular forward head **5636** and the cylindrical body **5637**. The cylindrical body **5637** of the sleeve bushing **5632** defines the central opening **5634** that receives the input shaft **5612** of the pinion gear **5610** to rotatably support the pinion gear **5610** in the gearbox housing **5113**. The cylindrical body **5637** of the larger sleeve bushing **5632** is supported within a conforming cavity **5129** (FIGS. **164**, **196** and **197**) of an inverted U-shaped forward section **5118** of the gearbox housing **5113**, while the enlarged forward head **5636** of the sleeve bushing **5632** fits within a conforming forward cavity **5126** of the U-shaped forward section **5118** of the gearbox housing **5113**.

A flat **5638** (FIG. **212**) of the enlarged forward head **5636** of the larger sleeve bushing **5632** interfits with a flat **5128** (FIG. **198**) of the inverted U-shaped forward section **5118** of the gearbox housing **5113** to prevent rotation of the sleeve bushing **5632** within the gearbox housing **5113**. As can best be seen in FIG. **212**, the sleeve bushing **5632** includes the longitudinal recess **5639** formed in an upper surface **5639***a* of the cylindrical body **5637**. The longitudinal recess **5639** is slightly below an upper surface of the flat **5638** of the annular forward head **5636**. When the sleeve bushing **5632** is inserted into the conforming cavity **5129** (FIGS. **164**, **196** and **197**) of an inverted U-shaped forward section **5118** of the gearbox housing **5113**, the sleeve bushing **5632** is positioned slightly higher in the gearbox housing **5113** than would otherwise be the case without the longitudinal recess **5639**. This results in both the pinion gear **5610** and the drive gear **5650** being positioned higher within the gearbox housing **5113** as well, as compared to the relative positions of, for example, the pinion gear **2610** and gearbox housing **2113** in the power operated rotary knife **2100**.

As the pinion gear **5610** and drive gear **5650** are substantially identical to the pinion gear **2610** and drive gear **2650** of the power operated rotary knife **2100**, the higher position of the pinion gear **5610** within the gearbox housing **5113** effectively raises the position of the drive gear **5650** with respect to the gearbox housing **5113**. Raising the position of the drive gear **5650** with respect to the gearbox housing **5113** allows for the lower spur gear **5654** of the drive gear **5650** to properly mesh with the driven gear **5328** of the rotary knife blade **5300**, as can be seen in FIG. **164**. This higher position of the lower spur gear **5654** is required because in the rotary knife blade **5300**, the position of the driven gear **5328** is axially higher (in the UP'''' direction) than was the case with the rotary knife blade **2300** of the power operated rotary knife **2100**. Comparing, for example, the schematic representations of the rotary knife blades **2300** and **5300** depicted in FIGS. **74** and **179**, one can readily see the relatively higher position of the driven gear **5328** with respect to the upper end **5306** of the body **5302** of the rotary knife blade **5300** compared to the driven gear **2328** with respect to the upper end **2306** of the body **2302** of the rotary knife blade **2300**.

The cylindrical body **5639** of the larger sleeve bushing **5632** defining the central opening **5634** provides radial bearing support for the pinion gear **5610**. The enlarged head **5636** of the sleeve bushing **5632** also provides a thrust bearing surface for a rearward collar **5627** (FIG. **197**) of the gear head **5614** to prevent axial movement of the pinion gear **5610** in the rearward direction RW'''', that is, travel of the pinion gear **5610** along the pinion gear axis of rotation PGR'''', in the rearward direction RW''''.

The bearing support assembly **5630** of the pinion gear **5610** also includes the smaller sleeve bushing **5640**. As can best be seen in FIG. **156**, the smaller sleeve bushing **5640** of the power operated rotary knife **5100** is similar to the smaller sleeve bushing **2640** of the power operated rotary knife **2100**. As best seen in FIGS. **190** and **196**, the smaller sleeve bushing **5640** includes an annular forward head **5644** and a cylindrical rearward portion **5642**. A forward facing surface **5624** of the gear head **5614** of the pinion gear **5610** includes a central recess **5626** which is substantially circular in cross section and is centered about the pinion gear axis of rotation PGR''''. The pinion gear central recess **5626** receives a cylindrical reward portion **5642** of the smaller sleeve bushing **5640**. The smaller sleeve bushing **5640** functions as a thrust bearing. The annular head **5644** of the smaller sleeve bushing **5640** provides a bearing surface for the gear head **5614** of the pinion gear **5610** and limits axial travel of the pinion gear **5610** in the forward direction FW'''', that is, travel of the pinion gear **5610** along the pinion gear axis of rotation PGR'''', in the forward direction FW''''.

As can best be seen in FIGS. **190** and **191**, the annular head **5644** of the smaller sleeve bushing **5640** includes two parallel peripheral flats **5648** to prevent rotation of sleeve bushing **5640** with rotation of the pinion gear **5610**. The parallel flats **5648** of the sleeve bushing **5640** fit within and bear against two spaced-apart parallel shoulders **5179** (FIG. **208**) defined by a U-shaped recess **5178** of an inner surface **5176** of a forward wall **5156** of the frame body **5150**. The abutment of the parallel flats **5648** of the smaller sleeve bushing **5640** against the shoulders **5179** of the frame body **5150** prevents rotation of the sleeve bushing **5640** as the pinion gear **5610** rotates about its axis of rotation PGR''''.

The drive gear bearing support assembly **5660**, in one exemplary embodiment, comprises a ball bearing assembly **5662** that supports the drive gear **5650** for rotation about the drive gear rotational axis DGR'. The drive gear bearing support assembly **5660** is secured to a downwardly extending projection **5142** (FIGS. **197-198** and **201**) of the inverted U-shaped central section **5118** of the gearbox housing **5113** by a fastener **5672**. The ball bearing assembly **5662** of the gearbox assembly **5112** is similar to the drive gear ball bearing assembly **2662** of the power operated rotary knife **2100**.

Gearbox Housing **5113**

As can best be seen in FIGS. **190-204**, the gearbox housing **5113** is part of the gearbox assembly **5112** and defines a gearbox cavity or opening **5114** that supports the gear train **5602** and the bearing support assemblies **5630**, **5660**. The gearbox housing **5113** includes a generally cylindrical rearward section **5116** (in the rearward direction RW"" away from the blade housing **5400**), the inverted U-shaped central section **5118**, and the forward mounting section **5120**. The gearbox housing **5113** extends between a proximal end **5122** defined by the rearward section **5116** and a distal end **5144** defined by the forward mounting section **5120**. The inverted U-shaped central section **5118** of the gearbox housing **5113** includes a rearward downwardly extending portion **5119** (FIG. **84**) and a forward portion **5125**.

The gearbox cavity or opening **5114** is defined in part by a throughbore **5115** which extends generally along the handle assembly longitudinal axis LA"" through the gearbox housing **5113** from the proximal end **5122** to the forward portion **5125** of the inverted U-shaped central section **5118**. As can best be seen in FIGS. **190-196**, the gear train **5604** is supported in and extends from the gearbox cavity **5114**. Specifically, the gear head **5614** of the pinion gear **5610** extends in the forward direction FW"" beyond the forward portion **5125** of the gearbox housing **5113** and portions of the drive gear **5650** extend in the forward direction beyond the rearward downwardly extending portion **5119** of the U-shaped central section **5118** of the gearbox housing **5113**. The inverted U-shaped central section **5118** and the cylindrical rearward section **5116** combine to define an upper surface **5130** of the gearbox housing **5113**.

The forward mounting section **5120** of the gearbox housing **5113** includes the L-shaped blade housing mounting pedestal **5132** that functions as a seating region to releasably receive the blade-blade housing combination **5550**. The L-shaped blade housing mounting pedestal **5132** includes a pair of spaced apart bosses **5131** that extend downwardly and forwardly from the forward portion **5125** of the inverted U-shaped central section **5118**. As can best be seen in FIGS. **198-204**, the pair of bosses **5131** each includes an upper horizontal portion **5131***a* and a lower vertical portion **5131***b*. A downward facing surface of the upper horizontal portion **5131***a* defines the first horizontal planar seating surface **5133** of the L-shaped blade housing mounting pedestal **5132**, while a forward facing surface of the lower vertical portion **5131***b* defines the second vertical planar seating surface **5134** of the L-shaped blade housing mounting pedestal **5132**.

The vertical planar seating surface **5134** is substantially orthogonal to the first horizontal planar seating surface **5133** and parallel to the axis of rotation R"" of the rotary knife blade **5300**. The horizontal planar seating surface **5133** is substantially parallel to the longitudinal axis LA"" of the handle assembly **5110** and the rotational plane RP"" of the rotary knife blade **5300**. The upper horizontal portion **5131***a* of each of the bosses **5131** includes a threaded opening **5135** that receives a threaded fastener **5191**. Each of the threaded fasteners **5191** pass through a respective opening **5430** of the blade housing mounting section **5402** and thread into a respective threaded opening **5135** of the bosses **5131** to secure the blade-blade housing combination **5550** to the gearbox housing **5313**.

A bottom portion **5141** (FIGS. **198** and **201**) of the forward portion **5125** of the inverted U-shaped middle section **5118** includes a downwardly extending projection **5142** (FIG. **198**). The downwardly extending projection **5142** includes a cylindrical stem portion **5143** and defines a threaded opening **5140** extending through the projection **5142**. A central axis through the threaded opening **5140** defines and is coincident with the axis of rotation DGR"" of the drive gear **5650**. The rearward downwardly extending portion **5119** of the inverted U-shaped central section **5118** of the gearbox housing **5113** defines upper and lower arcuate recesses **5119***a*, **5119***b* which provide for clearance of the bevel gear **5652** and the spur gear **5654** of the drive gear **5650**, respectively. The upper arcuate recess **5119***a* and the wider lower arcuate recesses **5119***b* are centered about the drive gear axis of rotation DGR"" and the central axis of the threaded opening **5140**. The inner surfaces of the pair of bosses **5131** also include upper and lower recesses **5131***c*, **5131***d* (best seen in FIGS. **198** and **199**) that provide for clearance of the bevel gear **5652** and the spur gear **5654** of the drive gear **5650**, respectively.

The throughbore **5115** of the gearbox housing **5113** provides a receptacle for the pinion gear **5610** and its associated bearing support assembly **5630** while the upper and lower arcuate recesses **5119***a*, **5119***b* provide clearance for the drive gear **5650** and its associate bearing support assembly **5660**. Specifically, with regard to the pinion bearing support assembly **5630**, the cylindrical body **5637** of the larger sleeve bushing **5632** fits within the cylindrical cavity **5129** (FIG. **204**) of the inverted U-shaped middle section **5118**. The enlarged forward head **5636** of the larger sleeve bushing **5632** fits within the forward cavity **5126** (FIGS. **198** and **204**) of the forward portion **5125**. The cylindrical cavity **5129** and the forward cavity **5126** of the inverted U-shaped central section **5118** of the gearbox housing **5113** are both part of the throughbore **5115**. When the larger sleeve bushing **5632** is positioned in the gearbox housing throughbore **5115**, the flat **5638** of the annular forward head **5636** bears against a flat **5128** formed in the forward cavity **5126** of the U-shaped central section **5118** of gearbox housing **5113** to prevent rotation of sleeve bushing **5632** within the gearbox housing **5113**. As discussed previously, the cylindrical body **5637** of the larger sleeve bushing **5632** includes a longitudinally extending recess **5639**. The longitudinal recess **5639** allows the cylindrical body **5637** to clear the flat **5128** of the forward cavity **5126** of the gearbox housing **5113**. Thus, the longitudinal recess **5639** of the larger sleeve bushing **5632** allows the throughbore **5115** and the gear train **5604** to be positioned slightly higher in the gearbox housing **5113**, as compared to the throughbore **2115** and gear train **5602** in the gearbox housing **2113** of the power operated rotary knife **2100**.

With regard to the upper and lower arcuate recesses **5119***a*, **5119***b*, the upper recess **5119***a* provides clearance for the first bevel gear **5652** of the drive gear **5650** as the drive gear **5650** rotates about its axis of rotation DGR"". The wider lower recess **5119***b* provides clearance for the second spur gear **5654** of the drive gear **5650** as the spur gear **5654** coacts with the rotary knife blade driven gear **5328** to rotate the rotary knife blade **5300** about its axis of rotation R"". As can best be seen in FIGS. **164** and **198**, the downwardly extending projection **5142** and the stem **5143** provide seating surfaces for the ball bearing assembly **5662**, which supports the drive gear **5650** for rotation within the rearward downwardly extending portion **5119** of the inverted U-shaped central section **5118** of the gearbox housing **5113**.

A cleaning port **5136** (FIGS. **198** and **201**) extends through the bottom section **5141** of the forward portion **5125** and through the rearward downwardly extending portion **5119** of the inverted U-shaped middle section **5118** of the gearbox housing **5113**. The cleaning port **5136** allows cleaning fluid flow injected into the throughbore **5115** of the gearbox housing **5113** from the proximal end **5122** of the gearbox housing **5113** to flow into the upper and lower arcuate recesses **5119***a*, **5119***b* for purpose of cleaning the drive gear **5650**.

As can be seen in FIG. **204**, the inner surface **5145** of the cylindrical rearward section **5116** of the gearbox housing **5113** defines a threaded region **5149**, adjacent the proximal end **5122** of the gearbox housing **5113**. The threaded region **5149** of the gearbox housing **5113** receives the mating threaded portion **5262** (FIG. **156**) of the elongated central core **5252** of the hand piece retaining assembly **5250** to secure the hand piece **5200** to the gearbox housing **5113**. As seen in FIGS. **198-201** and **203-204**, an outer surface **5146** of the cylindrical rearward section **5116** of the gearbox housing **5113** defines a first portion **5148** adjacent the proximal end **5122** and a second larger diameter portion **5147** disposed forward or in a forward direction FW'''' of the first portion **5148**. The first portion **5148** of the outer surface **5146** of the cylindrical rearward portion **5116** of the gearbox housing **5113** includes a plurality of axially extending splines **5148***a*. As was the case with the gearbox housing **2113** and the hand piece **2200** of the power operated rotary knife **2100**, the coacting plurality of splines **5148***a* of the gearbox housing **5113** and the ribs of the hand piece **5200** allow the hand piece **5200** to be oriented at any desired rotational position with respect to the gearbox housing **5113**.

The second larger diameter portion **5147** of the outer surface **5146** of the cylindrical rearward section **2116** of the gearbox housing **5113** is configured to receive a spacer ring **5290** (FIG. **156**) of the hand piece retaining assembly **5250**. Like the spacer ring **2290** of the power operated rotary knife **2100**, the spacer ring **5290** abuts and bears against a stepped shoulder **5147***a* defined between the cylindrical rearward section **5116** and the inverted U-shaped middle **5118** of the gearbox housing **5113**. A rear or proximal surface **5292** of the spacer ring **5290** acts as a stop for an axially stepped collar **5214** of the distal end portion **5210** of the hand piece **5200** when the hand piece **5200** is secured to the gearbox housing **5113** by the elongated central core **5252** of the hand piece retaining assembly **5250**.

The second larger diameter portion **2147** of the outer surface **2146** of the cylindrical rearward section **5116** of the gearbox housing **5113** also includes a plurality of splines (seen in FIGS. **198-199** and **201**). The plurality of splines of the second larger diameter portion **5147** is used in connection with an optional thumb support (not shown) that may be used in place of the spacer ring **5290**.

Frame Body **5150** and Frame Body Bottom Cover **5190**

As can best be seen in FIG. **158**, when the gear train **5604** is supported within the gearbox housing **5113**, portions of the pinion gear **5610** and the drive gear **5650** are exposed, that is, extend outwardly from the gearbox housing **5113**. The frame body **5150** and frame bottom cover **5190**, when secured together form an enclosure around the gearbox housing **5113** that advantageously functions to impede entry of debris into the gearbox housing **5113**, the pinion gear **5610** and portions of the drive gear **5650**. Additionally, the frame body **5150** includes portions that are adjacent to and extend the first horizontal planar seating surface **5133** and the second vertical planar seating surface **5134** of the L-shaped blade housing mounting pedestal **5132** defined by the pair of bosses **5131** of the gearbox housing **5113**. This advantageously enlarges the effective seating region of the gearbox housing **5113** for a more secure attachment of the blade-blade housing combination **5550** to the gearbox housing **5113**.

As can best be seen in FIGS. **165** and **205-205**, the frame body **5150** includes a central cylindrical region **5154** and a pair of outwardly extending arms **5152** from the central cylindrical region **5154**. The frame body **5150** includes a forward wall **5156** at a proximal or forward end of the frame body **5150**. A central portion **5156***a* of the forward wall **5156** is defined by the central cylindrical region **5154**, while forwardly extending portions **5156***b* of the forward wall **5156** are defined by the outwardly extending arms **5152**. In comparing FIGS. **162** and **67**, one can see an extended vertical height of the frame body **5150** of the power operated knife **5100** when compared to the frame body **2150** of the power operated rotary knife **2100**. The increased vertical height of the frame body **5150**, compared to the vertical height of the frame body **2150** of the power operated rotary knife **2100**, is necessitated by a lower position of the blade housing **5200** relative to the gearbox housing **5113** in the power operated rotary knife **5100**, as explained above.

As is best seen in FIG. **206**, proceeding in a rearward direction RW'''' from the forward wall **5156** toward a proximal end **5158** of the frame body **5150**, there are two tapered regions **5159** where the outwardly extending arms **5152** curve inwardly and blend into the central cylindrical region **5154**,

The frame body **5150** includes an outer surface **5170** and an inner surface **5172**. The inner surface **5172** defines the cavity **5174** (FIG. **205**) that slidably receives portions of the gearbox housing **5113** including the forward mounting section **5120** and the inverted U-shaped central section **5118**. As can best be seen in FIG. **165**, the frame body **5150** includes a bottom wall **5160** that includes a first, lower planar bottom wall portion **5162** and a second, upper planar bottom wall portion **5164**. As can be seen, the upper planar bottom wall portion **5164** is offset in an upward direction UP'''' from the lower planar bottom wall portion **5162**. The bottom wall **5160** is open into the cavity **5174** which allows the frame body **5150** to be slid over the upper surface **5130** of the gearbox housing **5113** in a relative downward direction DW'''' with respect to the gearbox housing **5113**. Specifically, a central dome-shaped portion **5180** of the cavity **5174** is configured to slidably receive the inverted U-shaped central section **5118** of the gearbox housing **5113**, while a pair of square-shaped portions **5182** of the cavity **5174** (FIG. **207**) flanking the central dome-shaped portion **5180** are configured to slidably receive respective ones of the pair of bosses **5131** of the forward mounting section **5120** of the gearbox housing **5113**.

When the frame body **5150** is fully slid onto the gearbox housing **5113**, the lower planar portion **5162** of the bottom wall **5160** of the frame body **5150** is flush with a bottom surface **5137** (FIGS. **198**, **199** and **201**) of the rearward downwardly extending portion **5119** of the inverted U-shaped central section **5118** of the gearbox housing **5113** and with a bottom surface **5137** of the lower vertical portions **5131***b* of the pair of bosses **5131**. Additionally, the upper planar portion **5164** of the bottom wall **5160** is flush with the first horizontal seating surface **5133** of the L-shaped blade housing mounting pedestal **5132**.

The upper planar portion **5164** of the bottom wall **5160** of the frame body **5150** continues and extends the effective seating region of the first horizontal seating surface **5133** of the L-shaped blade housing mounting pedestal **5132** of the gearbox housing **5113** for a more secure attachment of the blade-blade housing combination **5550** to the gearbox housing **5113**. Similarly, as can best be seen in FIGS. **158**, **205** and **207**, a narrow vertical wall **5188** between the upper planar portion **5164** and the lower planar portion **5162** of the bottom wall **5160** of the frame body **5160** is flush with the second vertical seating surface **5134** of the L-shaped blade housing mounting pedestal **5132** of the gearbox housing **5113**. The narrow vertical wall **5188** continues and extends the effective seating region of the second vertical seating surface **5134** of the L-shaped blade housing mounting pedestal **5132** of the gearbox housing **5113** for a more secure attachment of the blade-blade housing combination **5550** to the gearbox housing **5113**.

As can best be seen in FIG. **207**, the lower planar portion **5162** of the bottom wall **5160** includes a pair of threaded openings **5166**. The threaded openings **5166** receive respective threaded fasteners **5192** to secure the frame body bottom cover **5190** to the frame body **5150**. The inner surface **5176** of the forward wall **5156** of the frame body **5150** includes the U-shaped recess **5178** which defines the pair of spaced apart shoulders **5179** (FIG. **208**). As previously explained with respect to the smaller sleeve bushing **5642** of the pinion gear bearing support assembly **5130**, the shoulders **5179** provide an abutment or bearing surface for the pair of flats **5648** (FIGS. **190** and **191**) of the smaller sleeve bushing **5642** to prevent rotation of the sleeve bushing **5642** with rotation of the pinion gear **5610**. As can best be seen in FIGS. **205** and **207**, the inner surface **5172** of the frame body **5150** includes a pair of arcuate recesses **5184** adjacent the lower portion **5162** of the bottom wall **5160**. The pair of arcuate recesses **5184** provides clearance for the spur gear **5154** of the drive gear **5650** and continues the clearance surface defined by the lower arcuate recess **5119***b* of the rearward downwardly extending portion **5119** of inverted U-shaped central section **5118** of the gearbox housing **5113**.

As can best be seen in FIGS. **205** and **209-211**, the frame body bottom cover **5190** is a thin planar piece that includes an upper surface **5191**, facing the gearbox housing **5113**, and a lower surface **5192**. The frame body cover **5190** includes a pair of openings **5194** extending between the upper and lower surfaces **5191**, **5192**. The frame body bottom cover **2190** is removably secured to the frame body **5150** by the pair of threaded fasteners **5199** that extend through respective ones of the pair of openings **5113** and thread into respective threaded openings **5166** in the lower planar portion **5162** of the bottom wall **5160** of the frame body **5150**. The pair of openings **5194** include countersunk head portions **5194***a* formed in the lower surface **5192** of the frame body bottom cover **5190** such that, when the frame body bottom cover **5190** is secured to the frame body **5150**, the enlarged heads of the threaded fasteners **5199** are flush with the lower surface **5192**.

The frame body bottom cover **5190** also includes a straight forward wall **5195** and a contoured rearward wall **5196**. When the frame body bottom cover **5190** is secured to the frame body **5150**, the forward wall **5195** is flush with, continues and extends the effective seating region of the second vertical seating surface **5134** of the L-shaped blade housing mounting pedestal **5132** of the gearbox housing **5113** for a more secure attachment of the blade-blade housing combination **5550** to the gearbox housing **5113**. The contour of the rearward wall **5196** of the frame body bottom cover **5190** is configured such that, when the frame body bottom cover **5190** is secured to the frame body **5150**, a peripheral portion of the lower surface **5192** adjacent the rearward wall **5196** engages and seats against the lower planar portion **5162** of the bottom wall **5160** of the frame body **5150** and the bottom surface **5137** of the rearward downwardly extending portion **5119** of the inverted U-shaped central section **5118** of the gearbox housing **5113**. Because of the contoured configuration of the rearward wall **5196**, the lower surface **5192** of the frame body bottom cover **5190** thereby seals against both the gearbox housing **5113** and the frame body **5150** to protect the gearbox **5602** and specifically the drive gear **5650** and the drive gear ball bearing assembly **5662** from ingress of debris into the drive gear region.

In comparing FIGS. **67** and **164**, it can be seen that the height (or thickness) of the frame body bottom cover **5190** of the power operated rotary knife **5100** is greater than the corresponding height of the frame body bottom cover **2190** of the power operated rotary knife **2100**. This is because the frame body **5150** necessarily has a greater height than the frame body **2150** to account for the fact that the blade housing **5400** of the power operated rotary knife **5100** is positioned relatively lower with respect to the gearbox housing **5113**, as compared with the position of the blade housing **2400** with respect to the gearbox housing **2113** of the power operated rotary knife **2100**.

Securing Blade-Blade Housing Combination to Head Assembly **5111**

To removably attach the blade-blade housing combination **5550** to the gearbox housing **5113**, the upper end **5408** of the mounting section **5402** of the blade housing **5400** is aligned adjacent the horizontal planar seating surface **5133** of the L-shaped blade housing mounting pedestal **5132** of the forward mounting section **5120** of the gearbox housing **5113** and the outer wall **5406** of the blade housing mounting section **5402** is aligned adjacent the vertical planar seating surface **5134** of the L-shaped blade housing mounting pedestal **5132**. Specifically, the mounting section **5402** of the blade housing **5400** is aligned with the forward mounting section **5120** of the gearbox housing **5113** such that the two vertical apertures **5430** extending through the mounting section base **5428** and the pair of upright pedestals **5422** of the mounting section base **5428** are aligned with the vertically extending threaded openings **5135** through the pair of bosses **5131** of the forward mounting section **5120** of the gearbox housing **5113**.

When the blade housing **5400** is properly aligned with the forward mounting section **5120** of the gearbox housing **5113**, the upper surface **5428***a* of the base **5428** of the blade housing mounting section **5402** and the upper end **5440***a* of the blade housing plug **5440** affixed to the blade housing **5400** are in contact with the horizontal planar seating surface **5133** of the L-shaped blade housing mounting pedestal **5132**. Additionally, the rearward surface **5428***c* of the base **5428** of the blade housing mounting section **5402** and the outer wall **5440***d* of the blade housing plug **5440** are in contact with the vertical planar seating surface **5134** of the L-shaped blade housing mounting pedestal **5132**.

To affix the assembled blade-blade housing combination **5550** to the gearbox housing **5113**, the fasteners **5434** are inserted into the two vertical apertures **5430** of the blade housing mounting section **5402** and threaded into respective ones of the vertically extending threaded openings **5135** through the upper horizontal portions **5131***a* of the pair of bosses **5131** of the forward mounting section **5120** of the gearbox housing **5113**. When the blade housing **5400** is assembled to the gearbox housing **5113**, the plurality of spur gear drive teeth **5656** of the drive gear **5650** are in meshing engagement with the driven gear teeth **5330** of the rotary knife blade **5300** such that rotation of the drive gear **5650** about its axis of rotation DGR"" causes rotation of the rotary knife blade **5300** about its axis of rotation R"".

To remove the blade-blade housing combination **5550** from the gearbox housing **5113**, the pair of screws **5434** is unthreaded from the threaded openings **5135** of the upper horizontal portion **5131***a* of the pair of bosses **5131** of the forward mounting section **5120** of the gearbox housing **5113**. After the screws **5434** are completely unthreaded from the openings **5135**, the blade-blade housing combination **5550** will fall in a downward direction DW"" away from the gearbox assembly **5112**. The blade-blade housing combination

5550 may be removed from the gearbox housing **5113** without removal of the frame body **5150** or the frame body bottom cover **5190**.

As used herein, terms of orientation and/or direction such as front, rear, forward, rearward, distal, proximal, distally, proximally, upper, lower, inward, outward, inwardly, outwardly, horizontal, horizontally, vertical, vertically, axial, radial, longitudinal, axially, radially, longitudinally, etc., are provided for convenience purposes and relate generally to the orientation shown in the Figures and/or discussed in the Detailed Description. Such orientation/direction terms are not intended to limit the scope of the present disclosure, this application, and/or the invention or inventions described therein, and/or any of the claims appended hereto. Further, as used herein, the terms comprise, comprises, and comprising are taken to specify the presence of stated features, elements, integers, steps or components, but do not preclude the presence or addition of one or more other features, elements, integers, steps or components.

What have been described above are examples of the present disclosure/invention. It is, of course, not possible to describe every conceivable combination of components, assemblies, or methodologies for purposes of describing the present disclosure/invention, but one of ordinary skill in the art will recognize that many further combinations and permutations of the present disclosure/invention are possible. Accordingly, the present disclosure/invention is intended to embrace all such alterations, modifications, and variations that fall within the spirit and scope of the appended claims.

What is claimed is:

1. A power operated rotary knife comprising:

an annular rotary knife blade including a body and a blade section extending axially from the body, the body including an upper end and a lower end spaced axially apart and an inner wall and an outer wall spaced radially apart, the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and from the knife blade bearing surface;

a blade housing including a blade housing bearing surface; and

a blade-blade housing bearing structure disposed between the knife blade and the blade housing bearing surface to support the knife blade for rotation with respect to the blade housing.

2. The power operated rotary knife of claim **1** wherein the set of gear teeth of the knife blade are spaced axially below the knife blade bearing surface with respect to the upper end of the knife blade body.

3. The power operated rotary knife of claim **1** wherein the set of gear teeth of the knife blade are spaced axially above the knife blade bearing surface with respect to the upper end of the knife blade body.

4. The power operated rotary knife of claim **1** wherein the inner wall of the blade housing includes a radially extending projection axially aligned with and at least partially overlying the set of gear teeth of the knife blade.

5. The power operated rotary knife of claim **4** wherein the projection is spaced axially above the set of gear teeth with respect to the upper end of the knife blade body.

6. The power operated rotary knife of claim **1** wherein the outer wall of the knife blade includes a radially extending projection axially aligned with and at least partially overlying the set of gear teeth of the knife blade.

7. The power operated rotary knife of claim **6** wherein the projection extends radially outwardly beyond a cylinder defined by an outer surface of the set of gear teeth.

8. The power operated rotary knife of claim **6** wherein the projection is spaced axially below the set of gear teeth with respect to the upper end of the knife blade body.

9. The power operated rotary knife of claim **6** wherein the projection is a cap at the upper end of the knife blade body.

10. The power operated rotary knife of claim **1** wherein the knife blade bearing surface comprises a bearing race that extends inwardly into the outer wall of the knife blade body.

11. The power operated rotary knife of claim **10** wherein the knife blade bearing race is arcuate in a central portion of the bearing race.

12. An annular rotary knife blade for rotation about a central axis in a power operated rotary knife, the rotary knife blade comprising:

the annular rotary knife blade including a body and a blade section extending axially from the body, the body including an upper end and a lower end spaced axially apart and an inner wall and an outer wall spaced radially apart; and

the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and axially spaced from the knife blade bearing surface.

13. The rotary knife blade of claim **12** wherein the set of gear teeth are spaced axially below the bearing surface with respect to the upper end of the knife blade body.

14. The rotary knife blade of claim **12** wherein the set of gear teeth are spaced axially above the bearing surface with respect to the upper end of the knife blade body.

15. The rotary knife blade of claim **12** wherein the bearing surface comprises a bearing race that extends into the outer wail of the knife blade body and is arcuate in a central portion of the bearing race.

16. The rotary knife blade of claim **12** wherein the outer wall of the knife blade includes a radially extending projection axially aligned with and at least partially overlying the set of gear teeth of the knife blade.

17. The rotary knife blade of claim **16** wherein the projection extends radially outwardly beyond a cylinder defined by an outer surface of the set of gear teeth.

18. The rotary knife blade of claim **16** wherein the projection is spaced axially below the set of gear teeth with respect to the upper end of the knife blade body.

19. The rotary knife blade of claim **16** the projection is a cap at the upper end of the knife blade body.

20. The rotary knife blade of claim **12** wherein the set of gear teeth are involute gear teeth.

21. A power operated rotary knife comprising:

an annular rotary knife blade including a body and a blade section extending axially from the body, the body including an upper end and a lower end spaced axially apart and an inner wall and an outer wall spaced radially apart, the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and the knife blade bearing surface being axially above the set of gear teeth with respect to the upper end of the knife blade body; and

a blade housing, the rotary knife blade rotating in the blade housing about a central axis of rotation.

22. The power operated rotary knife of claim **21** wherein the knife blade bearing surface comprises a bearing race that extends inwardly into the outer wall of the knife blade body.

23. A power operated rotary knife comprising:

an annular rotary knife blade including a body and a blade section extending axially from the body, the body including an upper end and a lower end spaced axially apart and an inner wall and an outer wall spaced radially apart, the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and the knife blade bearing surface being axially below the set of gear teeth with respect to the upper end of the knife blade body; and

a blade housing, the rotary knife blade rotating in the blade housing about a central axis of rotation.

24. The power operated rotary knife of claim **21** wherein the knife blade bearing surface comprises a bearing race that extends inwardly into the outer wall of the knife blade body.

25. An annular rotary knife blade for rotation about a central axis in a power operated rotary knife, the rotary knife blade comprising:

the annular rotary knife blade including a body and a blade section extending axially from the body, the body including an upper end and a lower end spaced axially apart and an inner wall and an outer wall spaced radially apart; and

the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and axially above the knife blade bearing surface with respect to the upper end of the knife blade body.

26. The annular rotary knife blade of claim **25** wherein the knife blade bearing surface comprises a bearing race that extends inwardly into the outer wall of the knife blade body.

27. An annular rotary knife blade for rotation about a central axis in a power operated rotary knife, the rotary knife blade comprising:

the annular rotary knife blade including a body and a blade section extending axially from the body, the body including an upper end and a lower end spaced axially apart and an inner wall and an outer wall spaced radially apart, and

the outer wall defining a knife blade bearing surface and a set of gear teeth, the set of gear teeth being axially spaced from the upper end of the body and axially below the knife blade bearing surface with respect to the upper end of the knife blade body.

28. The annular rotary knife blade of claim **27** wherein the knife blade bearing surface comprises a bearing race that extends inwardly into the outer wall of the knife blade body.

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